International

Joint Commission

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A Report to
the Governments
of Canada and
the United States
on Reducing Flood
Impacts in the
Red River Basin

NOVEMBER 2000

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The International Joint Commission is a binational organization established by the Boundary Waters Treaty of 1909. The Commission helps Canada and the United States to manage the waters they share in a variety of ways, including investigating and reporting on issues when asked to do so by the two federal governments.

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International Joint Commission
Commission mixte internationale

November 28, 2000

Honorable Madeleine Albright
Secretary of State
2201 C St., NW
Washington, D.C. 20520

Honourable John Manley, P.C., M.P.
Minister of Foreign Affairs
125 Sussex Drive
Ottawa, Ontario K1A 0G2

Dear Secretary Albright and Minister Manley:

We have the honor to transmit herewith the Final Report of the International Joint Commission addressing issues arising from the 1997 flood on the Red River. This report was requested by the governments of Canada and the United States in the reference of June 12, 1997, concerning the causes and effects of damaging floods in the Red River basin, and follows up the Commission's Interim Report of December 31, 1997.

The Commission plans to release the report to the public on December 6, 2000.

Gerald E. Galloway
Secretary
United States Section

Murray Clamen
Secretary
Canadian Section

International

Joint Commission

Living with the Red

A Report to the Governments of Canada and the United States on Reducing Flood Impacts in the Red River Basin

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** C. Francis Murphy participated in the Commission's work under the Red River flooding reference until the expiration of his term as a Canadian Commissioner on September 1, 2000*

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Executive Summary

The flood of 1997 will long be remembered in the Red River basin of Canada and the United States. Over 100,000 people had their lives disrupted for several months and some still suffer from the physical and emotional trauma of the flood. Economic damages in the two countries approached U.S.$5 billion and flood recovery and mitigation costs continue to grow. Many of those who were not harmed by the flood recognize that their safety was preserved by only a matter of inches or centimeters. With great internal strength, basin residents on both sides of the border met the challenge of the flood but now look to governments to ensure that such destruction never again is visited upon them. At the request of Canadian Prime Minister Jean Chrétien and U.S. President William J. Clinton, the International Joint Commission undertook to analyze the root causes of the flood and to make recommendations as to how damage from major Red River floods could be mitigated in the future.

Since the summer of 1997, the Commission and its binational Task Force have been examining the flood and methods to reduce or eliminate the impacts of future major floods. In carrying out its responsibilities, the Task Force initiated the development of products that will be of continuing utility to the basin, including hydraulic models to aid in analysis of flood flows, high-resolution topographic and land use data for flood-prone areas and a virtual network to link those in the basin dealing with flood issues. The Commission has closely examined the work of the task force, conducted meetings and hearings in the basin, met with leaders at all levels in the public and private sector, and extended the analysis of the Task Force in some measure.

> *...what makes a community a place to live in is not the buildings, it's the people—the spirit and faith that are in those people. Water cannot wash that away, and fire cannot burn that away, and a blizzard cannot freeze that away. And if you don't give it away, it will bring you back better than ever.*
>
> Grand Forks Mayor Pat Owens,
> April 22, 1997

> *It is hard not to be touched by the sadness and enormous impact that the flood wrought on so many lives. But the flood also demonstrated how crisis brings out the best in people and in communities.*
>
> Winnipeg Mayor Susan Thompson,
> October 23, 1997

The Commission has come to the conclusions set out below:

- Flooding in the Red River basin is a natural hydrometeorological event. Although the 1997 flood was a rare event, floods of the same magnitude as 1997, or even greater, can be expected to occur in the future.
- The people and property of the Red River basin will remain at undue risk until comprehensive, integrated, binational solutions to flood problems are developed and implemented. Solutions for one part of the basin must take into account the impacts on other parts of the basin.

- There is no single solution to the flood damage mitigation challenge. To reduce vulnerability to flooding, all possible approaches, including both structural and non-structural damage reduction measures, must be considered as part of a comprehensive plan. This would include, when environmentally, economically and socially justified, development of additional reservoir storage, restoration of wetlands, micro-storage, construction or improvement of levees and dikes, floodwalls and bypass channels, permanent evacuation of high-risk areas, flood-proofing, and the enhancement of flood forecasting and warning systems.
- The potential flooding of major population centers in the Red River basin needs immediate attention:
  - The risk of a failure of Winnipeg's existing flood protection infrastructure is high under flow conditions similar to or greater than those experienced in 1997. While, for the most part, the city was spared significant damage in 1997, public safety requires that the city and province focus immediate attention on designing and implementing protective measures to further protect Winnipeg. These measures must respect both the needs of Winnipeg and the interests of those outside the city who might be affected by any such measures.
  - Detailed assessment of the significant flooding risks facing Fargo–Moorhead is required. Studies by the U.S. Army Corps of Engineers and the Federal Emergency Management Agency should be expedited so that appropriate mitigation measures can be identified and quickly implemented.
  - The work currently being undertaken in Grand Forks–East Grand Forks will serve to protect residents from future flood damage but needs to be completed in a timely manner and periodically evaluated for its level of protection.
  - Completion of studies, and development and implementation of proposed projects to protect Wahpeton and Breckenridge, should be expedited.
- The floodplain ecosystem of the Red River valley will be threatened unless steps are taken to protect it as part of the process of developing flood damage reduction solutions. In addition, steps must be taken to ensure that banned materials are removed from the basin and that storage of hazardous materials on the floodplain is carefully controlled.
- Governments at all levels need to promote a culture of flood preparedness and flood resiliency in the basin; continue the work begun by the Commission's Task Force; provide opportunities for multi-jurisdictional problem solving and the exchange of best-practices information; and integrate floodplain management activities into the broader field of watershed and basin management.

The Commission, in this report, has provided 28 recommendations for governments at all levels. The recommendations provide a blueprint for action. The challenge will come in the execution of these recommendations.

Federal, state, provincial and local governments have many well-established and active agencies dealing with various aspects of flooding within their jurisdictions. Non-governmental organizations also fill important flood-related roles. There also is a need for basin-wide binational institutional arrangements to deal with the transboundary issues that will arise, and the Commission finds that this need for a binational approach is generally accepted within the basin.

The Commission proposes to assign certain flood-related activities to its International Red River Board after consultations in the basin and with governments. The Commission also strongly recommends that:

- Governments immediately take steps, on a binational basis, to begin development of a comprehensive flood damage reduction plan for the Red River basin.
- Governments work with the International Red River Board and existing and emerging bilateral organizations to ensure that appropriate arrangements are in place for coordinating and implementing measures for flood-preparedness and mitigation activities, and to implement the recommendations of the Commission found in this report to governments.

Acknowledgments

The International Joint Commission (Commission) wishes to acknowledge the advice and work of others, without which this report would not have been possible. The Commission appreciates the information and many thoughtful comments and suggestions it received since the flood of 1997 from agencies, organizations, and individuals, either during the many public hearings and meetings in the Red River basin or through other venues. This dialogue helped to highlight important issues and often provided invaluable first-hand perspectives on the flood and its effects.

The Commission commends the International Red River Basin Task Force for its work, including the sound and very practical short-term guidance that the Commission passed on to governments in 1997, the extensive work that it undertook with respect to preparedness and mitigation for major floods in the basin, and, in particular, the foundation it laid for increased cross-border cooperation and improvements in data networks and modeling of river flows under flood conditions. These contributions will be of great assistance to the governments and residents of the Red River valley for years to come and will serve as the beginning of a legacy that the Commission leaves to the governments for their utilization. The Commission also acknowledges the important contributions to this report made by Commission staff.

Finally, the Commission wishes to express its respect for the people of the Red River basin. Following the terrible destruction and suffering caused by the flood of 1997, basin residents have shown the two countries countless ways in which progress can be made in recovering from flood damage and in becoming better prepared for future floods. The Commission acknowledges the many efforts, great and small, that together are leading to the development of a truly resilient Red River basin community.

1

Introduction

The fall of 1996 in the Red River basin was wetter than normal. Winter brought record or near-record snowfall throughout the basin, and heavy precipitation continued in the early spring of 1997. The snow began to melt in the southern portion of the basin in the latter part of March. Then, a major blizzard swept through the basin in early April leaving up to 48 centimeters (cm), or 19 inches, of snow over most of the valley. Forecasters immediately recognized the consequences. As floodwaters began their inevitable journey downstream, cities and residents intensified their flood preparation efforts. The flood reached record height as it passed Wahpeton–Breckenridge and Fargo–Moorhead, flooding the former but largely sparing the latter. The countries watched in horror as floodwaters claimed Grand Forks–East Grand Forks on April 22 and a major fire burned uncontrolled in downtown Grand Forks. The waters moved northward across the Canada–United States boundary, at which point they formed a great inland sea, stretching to a width of 16 kilometers (km), or 10 miles. Individual homes, communities and farmsteads were inundated and ring-diked communities were evacuated as the floodwaters headed northward toward Winnipeg. City, town and rural residents teamed with the largest deployment of Canadian troops since the Korean War to shore up flood defenses. The Winnipeg Floodway, an excavated channel constructed in the 1960s, diverted floodwaters around Winnipeg. Throughout the basin, over 100,000 people were evacuated. Roads and railway lines were impassable. Lives were disrupted.

Recognizing the devastating effects of the flood on both sides of the border and the need for cross-border cooperation in addressing flood-related issues, U.S. President Bill Clinton and Canadian Prime Minister Jean Chrétien agreed to ask the International Joint Commission (IJC), referred to hereafter as the Commission, to study the flood and its impacts. On June 12, 1997, the governments of Canada and the United States gave the Commission a reference under Article IX of the Boundary Waters Treaty of 1909 to examine and report on the causes and effects of damaging floods in the Red River basin, and to make recommendations on means to reduce, mitigate and prevent harm from future flooding in the basin. A copy of the reference is attached as Appendix 1.

Note on the Commission's and Task Force's Conclusions and Recommendations

1. The Commission endorses most of the conclusions and recommendations contained in the final report of the International Red River Basin Task Force.
2. In view of their particular importance, certain conclusions and recommendations of the Task Force endorsed by the Commission are cited in full in the text of this report. Others are simply mentioned in summary form.
3. In some cases, the Commission has modified conclusions and recommendations advanced by the Task Force. Such modifications are given in full in the text of the report.
4. In other cases, the Commission draws conclusions and makes recommendations of its own. Such conclusions and recommendations are given in full in the text of the report.
5. For convenient reference, Appendix 2 to this report sets out the Commission's position on each of the conclusions and recommendations of the Task Force.

The Commission established a binational Task Force with experts from the two countries to assist it in responding to the reference. Based on advice from the Task Force, the Commission issued an interim report to governments in December 1997. The report identified measures that needed to be implemented in the near term to reduce the potential for damage from a flood in 1998. The Commission held public hearings in the basin to obtain views from the public on the interim report.[1] In April 2000, the Commission received the Task Force's final report and, in May 2000, held public hearings and meetings in the basin[2] to obtain comment on the information, conclusions, and recommendations of the Task Force.

This report is the final report of the International Joint Commission to the two governments under the reference.[3] The report is based on input received from a number of sources: the interim and final reports of the Task Force, views expressed by officials and residents of the basin at public hearings and other venues, and information obtained by the Commission throughout the study.

In this report, the Commission endorses most of the Task Force's conclusions and recommendations, modifies some, and adds some new conclusions and recommendations of its own. Appendix 2 to this report sets out the Commission's position with respect to each of the conclusions and recommendations of the Task Force and indicates where they have been modified or supplemented by conclusions and recommendations of the Commission. A complete list of the Commission's conclusions and recommendations is given in Section 9.

The Commission's interim report to the governments of December 1997 and the final report of the Task Force *The Next Flood: Getting Prepared* of April 2000 are included as appendices 3 and 4, respectively. Together, these documents provide advice with respect to improvements required to be better prepared for future flood events in the Red River basin.

---

[1] Public hearings were held in February 1998 at Grand Forks, North Dakota; Moorhead, Minnesota; Pembina, North Dakota; Ste. Agathe, Manitoba; and Winnipeg, Manitoba.

[2] Public hearings were held in May 2000 at Emerson, Manitoba; Fargo, North Dakota; and Winnipeg, Manitoba; meetings were held in May 2000 at Morris, Manitoba, and Grand Forks, North Dakota.

[3] The Commission's report is also available on the Internet at www.ijc.org

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2

Geography and Flood History

The Red River, or Red River of the North as it is known in the United States, flows north from its headwaters in Minnesota to its outlet at Lake Winnipeg in Manitoba, meandering through the flat and fertile valley of the former glacial Lake Agassiz. The river basin occupies substantial portions of North Dakota, northwestern Minnesota, southern Manitoba and a very small portion of northeastern South Dakota. It covers 116,500 square kilometers (km^2) or 45,000 square miles, excluding the Assiniboine River basin, which joins the Red River at Winnipeg. A map of the basin is shown in Figure 1.

The basin is remarkably flat. At Wahpeton, North Dakota, the elevation is 287 meters (m), or 943 feet, above sea level. At Lake Winnipeg, the elevation is 218 m (714 feet), a difference of only 70 m (229 feet) over a distance of about 877 river km (545 miles). The slope of the river averages less than one tenth of a meter per kilometer (less than one half foot per mile), varying from about 0.25 m/km (1.3 feet per mile) near Wahpeton to 0.04 m/km (0.2 feet per mile) near the Manitoba border. The flattest portion of the basin, located along the river and known colloquially as the Red River valley, is about 100 km (60 miles) across at its widest. During the 1997 flood, the river spread to a maximum width of about 40 km (25 miles) in Manitoba. The floodplain features natural levees[4] along some reaches of the Red River and its tributaries. When these levees are overtopped or bypassed, land for several miles on each side may be flooded. The floodplain has clay soils with low absorptive capacity that can contribute to flood problems. Furthermore, the river's northward flow increases the potential for ice jams and resultant backwater flooding. The largest floods usually occur following heavy precipitation the previous fall, hard and deep frost prior to snowfall, substantial snowfall, and heavy rainfall or wet snow conditions during the spring breakup.

The largest population center in the basin is Winnipeg, with a population of about 670,000. Other major population centers are: Fargo–Moorhead (population over 100,000), Grand Forks–East Grand Forks (population 60,000), Wahpeton–Breckenridge (population 12,000), and Selkirk (population 9,800). These major population centers are located on the banks of the Red River. The floodplain of the Red River valley is also a highly productive agricultural area. Thus, much of the basin's urban and rural populations are at risk from flooding.

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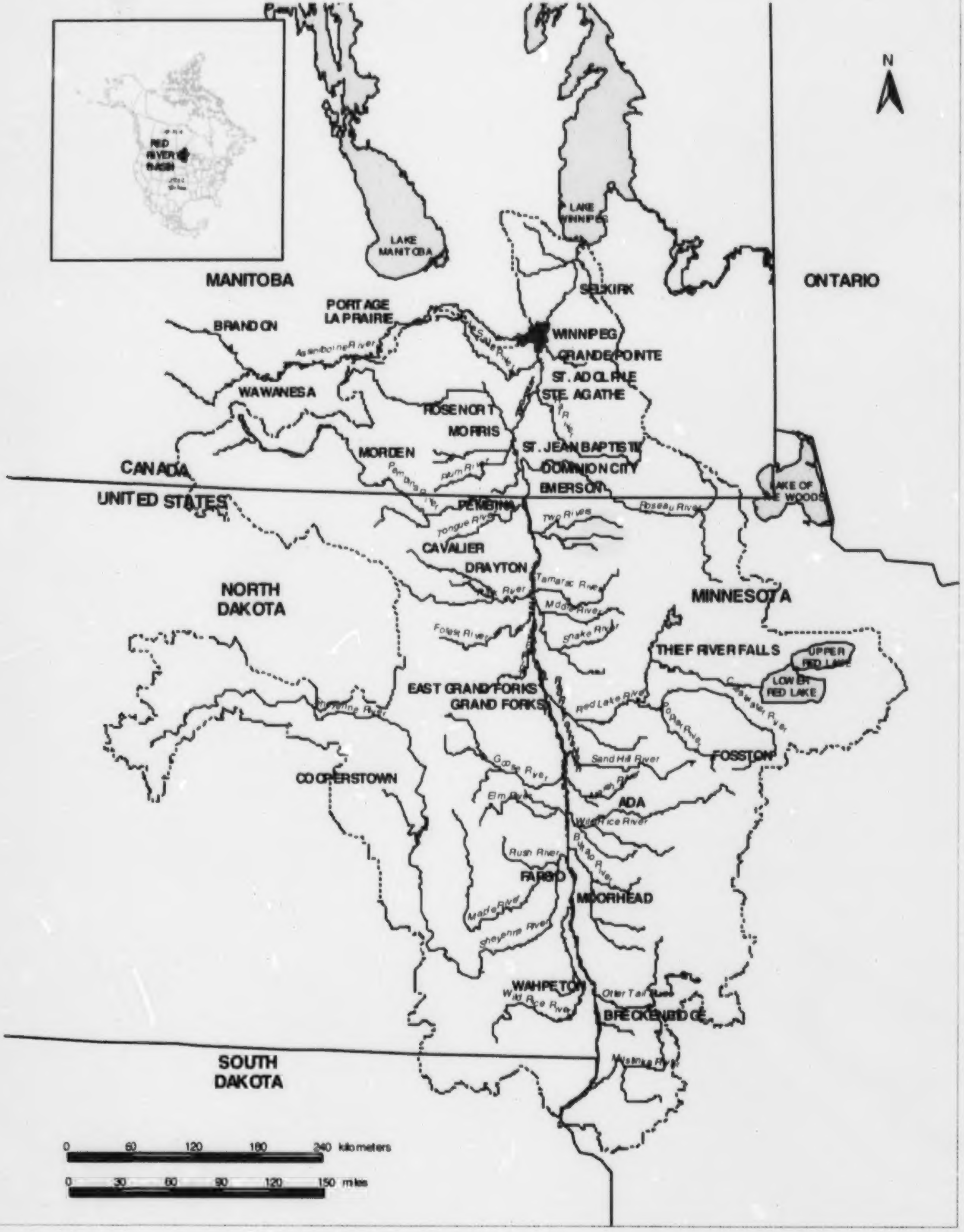
[4] In the United States, the term "levee" is commonly used for riverside flood control works; in Canada, the term used is "dike." In this report the terms are used interchangeably.

Figure 1

Map of the Red River Basin


RED RIVER BASIN
LAKE MANITOBA
LAKE WINNIPEG
N
MANITOBA
ONTARIO
SELKIRK
PORTAGE LA PRAIRIE
BRANDON
Assiniboine River
La Salle River
WINNIPEG
GRANDE POINTE
ST. ADOLPHE
STE. AGATHE
ROSENORT
MORRIS
WAWANESA
MORDEN
Pembina River
Plum River
ST. JEAN BAPTISTE
DOMINION CITY
EMERSON
CANADA
UNITED STATES
PEMBINA
LAKE OF THE WOODS
Two Rivers
Roseau River
Tongue River
CAVALIER
DRAYTON
Tamarac River
Park River
Middle River
NORTH DAKOTA
MINNESOTA
Forest River
Snake River
THIEF RIVER FALLS
UPPER RED LAKE
LOWER RED LAKE
Clearwater River
EAST GRAND FORKS
GRAND FORKS
Red Lake River
Red River
Sheyenne River
Poplar River
FOSSTON
Sand Hill River
COOPERSTOWN
Goose River
Marsh River
Elm River
ADA
Wild Rice River
Buffalo River
Rush River
FARGO
MOORHEAD
Maple River
Sheyenne River
WAHPETON
Wild Rice River
Otter Tail River
BRECKENRIDGE
SOUTH DAKOTA
Mustinka River
0 60 120 180 240 kilometers
0 30 60 90 120 150 miles

Historic analyses show that flows of the Red River are erratic and highly variable, forcing residents along its length to deal with floods and droughts. Major floods have occurred as recently as 1950 and 1979. The spring of 1997 brought the largest flood on record along much of the river. Heavy precipitation fell in the fall of 1996—as much as 15 cm (6 inches) in late October and November—leading to high soil moisture in the basin. Winter brought record or near-record snowfall throughout the basin, with many areas experiencing two to three times the average. On April 5–6, a blizzard dumped wet snow on the basin. Temperatures remained cool, then warmed suddenly, sending meltwater surging downstream. Table 1 shows peak flows at several locations along the Red River.

North Dakota Institute for Regional Studies, NDSU

The 1897 flood of the Red River of the North at Fargo–Moorhead.

The 1997 flood had about the same volume of water as did the 1950 flood, but had a peak that was much higher and of shorter duration. In the United States, flood stages at 29 of the 34 recording stations in the Red River basin exceeded previous floods of record. At Winnipeg, the 1826 flood remains the largest on record (it was not recorded in the U.S. portion of the basin). The 1997 flood was the largest in the Manitoba portion since current settlement patterns were established. The map in Figure 2 shows the general extent of the 1997 flood.

Table 1

1997 Red River Peak Flows

Location	Date	Peak Flow *
Wahpeton–Breckenridge	April 15	362 cms (12,800 cfs)
Fargo–Moorhead	April 17	793 cms (28,000 cfs)
Grand Forks–East Grand Forks	April 18	3880 cms (137,000 cfs)
Drayton	April 25	3510 cms (124,000 cfs)
Emerson	April 27–28	3910 cms (138,000 cfs)
Ste. Agathe	May 2	3820 cms (135,000 cfs)
Winnipeg **	May 4	4590 cms (162,000 cfs)

* cms—cubic meters per second; cfs—cubic feet per second

** Total discharge at Winnipeg including flows in river channel and the Winnipeg Floodway.

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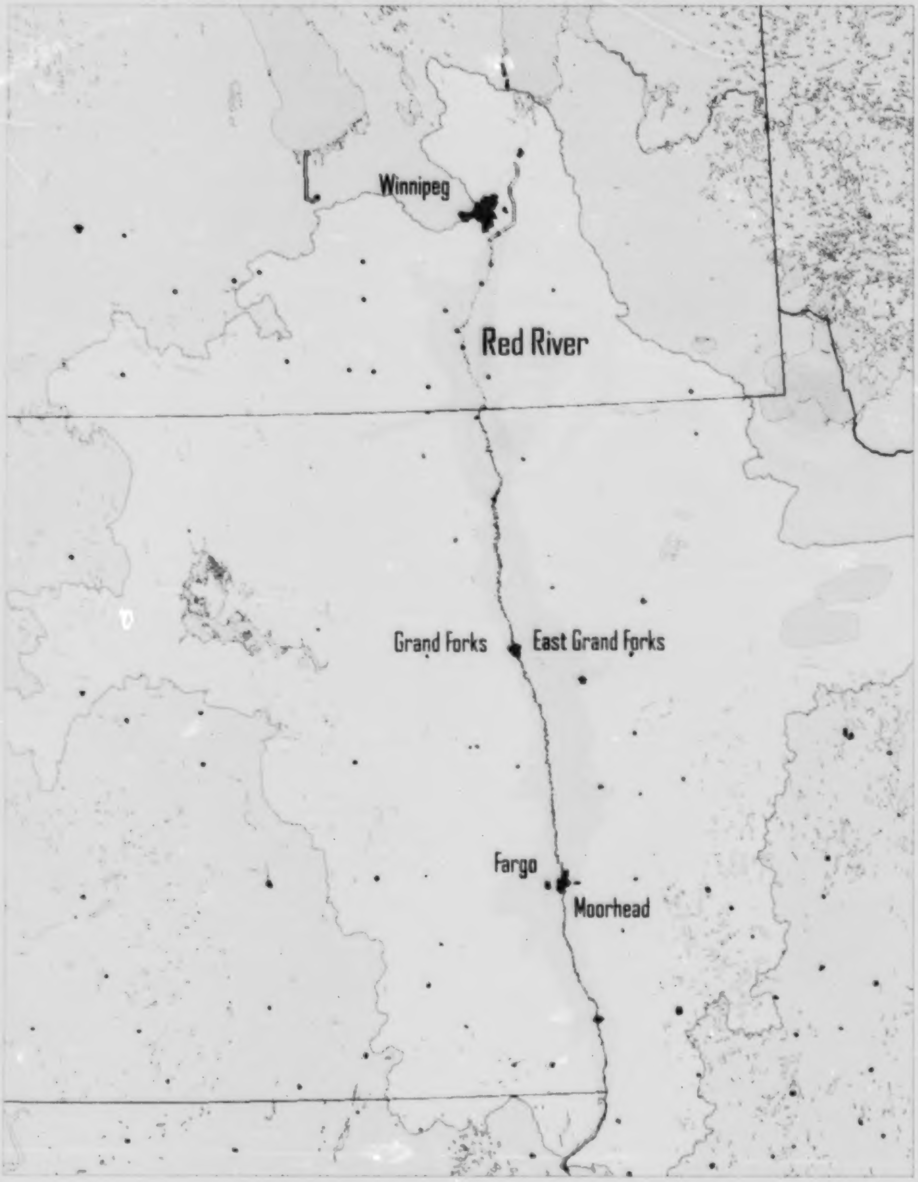
* cms—cubic meters per second; cfs—cubic feet per second
** Total discharge at Winnipeg including flows in river channel and the Winnipeg Floodway.

Figure 2

Generalized Extent of the 1997 Flood, Including Overland Flow


Winnipeg
Red River
Grand Forks
East Grand Forks
Fargo
Moorhead

U.S. Army Corps of Engineers, St. Paul District, and Engineering Research and Development Center, Hanover

3

The Reference

In its June 1997 reference, the governments asked the Commission to examine and report on the causes and effects of damaging floods in the Red River basin, and to make recommendations on means to reduce, mitigate and prevent harm from future flooding. Acknowledging the need for a cooperative approach to ensure better preparedness and response to future floods, the governments asked the Commission to focus on cross-border cooperation between governments, agencies, communities and other interests.

Extract from Canadian and U.S. Governments' Reference to the International Joint Commission—June 12, 1997

- ...examine and report on the causes and effects of damaging floods in the Red River basin, and to make recommendations on means to reduce, mitigate and prevent harm from future flooding in the Red River basin.
- ...focus on cross-border cooperation of governments, agencies and communities in the basin in its inquiries under this reference.
- ...identify strengths and capabilities, to be able to identify vulnerable areas in effectiveness, emergency preparedness programs and in response planning, and other flood-related problems, and to point the way toward improvements in these measures.
- ...examine and make recommendations on:
  - ...remedial, restorative, protective or management measures that would help to mitigate the effects of flooding;
  - ...innovative measures for flood reduction, damage reduction and future relief options...;
  - ...scientific and technical investigations, applied research or demonstration projects relating to enhanced flood protection and mitigation;
  - ...the relevant information base, including monitoring and alerting networks, and its integration with respect to the Red River basin;
  - ...the objectives, parameters, organization and structure of bilateral cooperation and measures for its improvement;
  - ...a plan or plans of cooperative flood management, flood forecasting, emergency response and flood mitigation;
  - ...any other matters that the Commission deems appropriate and relevant.
- ...take account of the principles of sustainable development and ecosystem management...
- note that a variety of initiatives are underway on various matters pertaining to water or land use management, emergency preparedness and response and environmental data gathering and monitoring...draw upon these initiatives.

Note: See Appendix 1 for full text of reference.

3

The Reference

In its June 1997 reference, the governments asked the Commission to examine and report on the causes and effects of damaging floods in the Red River basin, and to make recommendations on means to reduce, mitigate and prevent harm from future flooding. Acknowledging the need for a cooperative approach to ensure better preparedness and response to future floods, the governments asked the Commission to focus on cross-border cooperation between governments, agencies, communities and other interests.

Extract from Canadian and U.S. Governments' Reference to the International Joint Commission—June 12, 1997

- ...examine and report on the causes and effects of damaging floods in the Red River basin, and to make recommendations on means to reduce, mitigate and prevent harm from future flooding in the Red River basin.
- ...focus on cross-border cooperation of governments, agencies and communities in the basin in its inquiries under this reference.
- ...identify strengths and capabilities, to be able to identify vulnerable areas in effectiveness, emergency preparedness programs and in response planning, and other flood-related problems, and to point the way toward improvements in these measures.
- ...examine and make recommendations on:
  - ...remedial, restorative, protective or management measures that would help to mitigate the effects of flooding;
  - ...innovative measures for flood reduction, damage reduction and future relief options...;
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Having urged the Commission to draw upon available expertise, data, technology and relevant studies, the two governments undertook to seek the funds required to provide promptly to the Commission the resources needed to discharge its obligations under the reference. The Commission was asked to provide an interim report by December 31, 1997, identifying near-term measures, and to make a full report, including recommendations for areas requiring further study, before the end of 1998. Because of U.S. funding shortfalls, the scope of study was curtailed and the deadline for the full report was extended to December 2000.

4

The Study

The Commission established a binational and multidisciplinary International Red River Basin Task Force[5] to assist with the studies required under the reference. The Task Force was composed of 10 members, five from Canada and five from the United States. As is customary in Commission studies, Task Force members worked in the spirit of consensus and served in their personal and professional capacities, not as representatives of their countries or employers.

The two federal governments provided funds for the study. On the Canadian side, the full share of half the projected cost, or Can$4 million,[6] was provided at the outset. On the U.S. side, study funding was subject to the U.S. budget process. Limited U.S. funding was made available in 1997 to enable work on the interim report and subsequent public hearings. Approximately U.S.$787,000 was made available in October 1998, and approximately U.S.$100,000 in October 1999. The Task Force was able to leverage the reach of its funds on both sides of the border by partnering with others on areas of mutual interest, such as with the Global Disaster Information Network (GDIN) on the U.S. side and with the city of Winnipeg and the province of Manitoba on the Canadian side. The uncertainty of the amount and timing of U.S. funding caused great difficulties: studies had to be deferred or curtailed, schedules had to be extended, and work plans had to be revised numerous times to reflect changing expectations and understandings regarding the funds available. These funding difficulties also made full binational partnership in the conduct of the Task Force's work much more challenging.

Commissioners visited the basin in May 1997, viewed the ongoing flood and its impacts by helicopter and small plane, and saw the immediate aftermath of the flood and fire in Grand Forks and East Grand Forks. During this visit, Commissioners also received initial briefings by Canadian and U.S. personnel knowledgeable about the flood and efforts to fight it. During September and October 1997, Commissioners and members of the Task Force again toured some of the hardest-hit areas of the basin. They held briefing and fact-finding sessions with civic and community leaders in Fargo, North Dakota; Moorhead, Minnesota; Grand Forks, North Dakota; East Grand Forks, Minnesota; and Morris, Manitoba; and met with political leaders in each of the jurisdictions. Detailed interviews were conducted with families affected by the flood and with civic officials and local emergency management coordinators. Over the duration of the study, Task Force members and Commissioners attended a range of workshops, meetings and forums throughout the basin to hear from members of the public as well as elected and public officials. The Commission kept abreast of initiatives by other groups and jurisdictions in the basin, including by the Manitoba

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[5] Subsequently, in this report, this body will be referred to as "the Task Force."

[6] The exchange rate during the study was approximately Can$1 = U.S.$0.66.

Water Resources Commission, the President's Long-Term Recovery Task Force, the U.S. Army Corps of Engineers' analysis of flood protection measures for the cities of Grand Forks and East Grand Forks, the International Flood Mitigation Initiative (IFMI), and numerous other efforts aimed at ensuring better flood preparedness in the valley. A number of Task Force members represented their agencies or participated in many of these efforts. Credit must be given to federal agencies, and state, provincial and local governments for the recovery plans and mitigation efforts that have been put in place or are in progress. Much has been accomplished, but much remains to be done to ensure that a flood similar to that of 1997, or larger, will never again cause the damage, dislocation and disruption that resulted from the 1997 flood.

The Task Force submitted its interim report *Red River Flooding: Short-Term Measures*[7] to the Commission in December 1997. In addition to providing a description of the Red River basin and its flood history, the report examined the 1997 flood from a number of perspectives and made 40 recommendations that could be implemented in the near term to help in preventing or minimizing damage from future floods. Among the issues addressed were emergency preparedness, response, recovery, and mitigation.

Based on the Task Force's interim report and what it heard from residents of the basin, the Commission submitted its interim report to the governments on December 31, 1997. In that report, the Commission commended governments and organizations for the spirit of cooperation demonstrated in preparing for and fighting the 1997 flood, and for the efforts being made to better prepare for future floods. Further, the Commission endorsed the recommendations contained in the interim report of the Task Force. It encouraged governments at the federal, state, provincial and municipal levels to work together to implement the recommendations to minimize damage from possible flooding that could occur in the short term. While governments have been responsive to the Commission's recommendations, the Commission notes that there are still areas where additional action concerning cross-border coordination and cooperation on data enhancement and model development would improve flood preparedness. Those regarding data and model development are largely addressed in this report. The interim report recommendation calling for a meeting of senior officials warrants reconsideration in the context of a five-year review of actions taken to prepare for future major floods in the basin. To this end, the Commission recommends that:

> **IJC Recommendation 1:** ***The federal governments should convene a meeting of senior federal, provincial and state officials in 2002 to undertake policy discussions and an examination of the 1997 flood, with emphasis on review of emergency plans, evacuation procedures and mitigation measures underway.***

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[7] *Interim Report of the International Red River Basin Task Force, Red River Flooding: Short-Term Measures,* (December 1997). (Available at: www.ijc.org)

The Task Force's interim report also outlined a plan of study for undertaking further work to prevent or reduce flood damage and to improve tools for planning and decision making for better floodplain management. This plan of study focused on a single aspect of water management—flooding, specifically the flood of 1997—and defined three specific objectives for its investigations: develop and recommend a range of alternatives to prevent or reduce future flood damage, improve tools for planning and decision making, and facilitate integrated flood emergency management in the basin. Alterations to the plan of study were made over the course of the study, both to adjust to funding uncertainties and to reflect the outcome of work undertaken by the Task Force or other organizations.

During the course of its work, the Task Force funded data collection, hydraulic model development, the initiation of virtual databases and communications networks, studies of the social impacts of flooding, and reviews of available information for such purposes as water quality assessments and effects of flood control operations. It teamed with other organizations and agencies in both countries to further common goals. After concluding its major studies, the Task Force prepared and submitted its final report to the Commission.[8] The Commission has drawn heavily from the Task Force's work for this report to governments and believes that the information and tools the Task Force developed will continue to prove useful to those in the basin who are dealing with floods.

Many people who attended the Commission's public hearings in May 2000 expressed concern over issues not addressed in the Task Force's work. The Commission recognizes that there are many issues associated with floods and flooding, and that it has not addressed them all. This report points out areas requiring further consideration. The Commission encourages the governments to continue the necessary work to ensure appropriate understanding of flood-related issues so that flood preparedness in the Red River basin can continue to improve.

The following chapters describe major issues regarding flood preparedness and mitigation, and offer conclusions and recommendations intended to guide further efforts to reduce flood risks. While the report is submitted to the two federal governments in fulfillment of its responsibilities under the reference, the Commission nevertheless considers its report to be for the people of the basin, and for those governmental and other organizations that work to reduce the devastating effects of large floods.

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[8] In order to provide context for discussion of the Task Force's conclusions and recommendations, the Task Force's report, less the executive summary and appendices, is included as Appendix 4. The full report is available, along with supporting reports, at www.ijc.org.

5

Preparing for the Next Flood

A. Flooding in the Red River Basin

The first settlers in the basin established their communities along the Red River—the principal transport route into the region. These settlement patterns set the stage for most of today's flooding problems. Communities located along the water transportation corridor for convenience and to enjoy the beauty of the river. Many were unaware of or ignored the potential flood threat of the river. Floods occur throughout the valley and along the tributaries in various degrees of severity. Some affect small local areas; others affect larger regions. Some last for a few hours or a few days; others disrupt normal activity for periods of several weeks or months.

The relatively flat topography of the basin places most of its residents on or near the floodplain of the river, and for economic and social reasons this is unlikely to change. Flooding can occur in successive years or there can be several years between floods. They can occur as a result of spring snow melt, perhaps aggravated by coincident rainfall, or as a result of heavy summer rains.

In its interim report, the Task Force stated that a flood of the magnitude of the 1997 flood could happen in any year. The Task Force subsequently conducted investigations to gain a better appreciation of the frequency and size of major floods that might occur in the valley, extrapolating from the early flood history of the Red River. It examined sediment deposits and early evidence of settlement, analyzed tree ring histories, and reviewed the regional climate. In addition, the Task Force conducted detailed hydrometeorological analyses in which, using historical data, it simulated 2,000 large floods at Winnipeg. The largest simulated flood had a peak flow of approximately 8495 cubic meters per second (cms), or 300,000 cubic feet per second (cfs). Subsequent statistical analysis by the province of Manitoba has shown that the 1997 flood has about a 90-year recurrence interval at Winnipeg, while the 1826 flood has about a 300-year recurrence interval.

In the U.S. portion of the basin, flow data are not available for the period prior to 1873 when a gauging station was established at Grand Forks. The 1826 flood was not documented in the United States. However, a model was developed to simulate one possible flooding scenario that would yield the discharges experienced at Winnipeg in 1826.[9] This model shows estimated flood levels[10] of about 6.2 m (20.3 feet) at Wahpeton–Breckenridge, 13.0 m (42.5 feet) at Fargo–Moorhead, 17.4 m (57.0 feet) at Grand Forks–East Grand Forks, and 14.4 m (47.1 feet) at Drayton, with an estimated accuracy of plus or minus one foot.[11] Prior to 1997, the greatest flood on record in the U.S. portion of the basin occurred in 1897 with a peak discharge of 2410 cms (85,000 cfs) at Grand Forks. This was significantly less than the peak of 3880 cms (137,000 cfs) at Grand Forks recorded in 1997. In May 2000, the U.S. Army Corps of Engineers issued a draft discharge-frequency study, estimating the approximate recurrence intervals of the 1997 Red River flood at various mainstem locations, based on instantaneous peaks reported by the U.S. Geological Survey.

Recurrence Intervals

Floods are often identified by recurrence interval, such as a "100-year flood." Recurrence intervals are usually determined by performing statistical analyses on many years of flood elevation and flood discharge data. The more data available, the greater the confidence that can be placed in the estimated recurrence interval. New data, especially for larger and more infrequent floods, help to refine estimated recurrence intervals and often lead to a change in the interval following a large flood.

But what is a 100-year flood? A 100-year flood has a 1-percent chance of being equaled or exceeded in any given year. (A 2-percent chance flood has a one in fifty chance of occurrence in any given year.) The risk of a 100-year flood is the same every year, regardless of whether there was a 100-year flood the year before or 99 years before. A 100-year flood has a 26-percent chance of occurring over the life of a 30-year mortgage, and a 63-percent chance of occurring over the next 100-years. The terms 100-year flood, 100-year recurrence interval flood, 100-year frequency flood, 1-percent flood, 1-percent annual chance flood and, in the United States, base flood all refer to the same event and are used interchangeably.

The geographic area expected to be inundated by a given flood, such as the 100-year flood, can be shown on floodplain maps. Often, building regulations or restrictions are applied within a mapped "regulatory" floodplain, which is usually based on the 100-year flood. Flood risk is not the same everywhere within a mapped floodplain; sites at lower elevations have greater flood risk. It must also be recognized that floods larger than any specific flood used for regulatory or other purposes could occur, and that even sites located outside a mapped floodplain may be at risk from these larger floods.

The severity of a flood, based on statistical analysis, usually varies as it moves downstream. Table 2 shows the estimated recurrence interval of the 1997 flood at various locations along the Red River.

The data concerning past and future flooding produced by the Task Force includes recorded data as well as statistical estimates of extreme flood events. The estimates provide a sound basis for general conclusions concerning flooding. Recent climate variability and possible climate change make for greater uncertainty. Nevertheless, the Commission concludes that:

> **IJC Conclusion 1:** ***Although the 1997 flood was a rare event, floods of the same size as the 1997 event, or greater, can be expected to occur in the future in the Red River basin. People and property remain at risk from these floods.***

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[9] U.S. Army Corps of Engineers' UNET model for the Red River, developed by the St. Paul District and further refined by the Hydrologic Engineering Center.

[10] Flood elevations in the U.S. portion of the basin are referenced to local gauge height.

[11] These model results assume that levees contain flood flows and bridges remain in place.

Flooding in the Red River basin results from the combination of high flows in the Red River and its tributaries, and the topography and development of the basin places people and property at risk. The loss of wetlands and construction of farm and urban drainage have increased runoff from the land into streams and rivers and may aggravate the damage caused by floods. While it is not possible to stop floods from occurring, or to entirely prevent damage from floods, a wide variety of actions can and should be taken that will prevent some damage, and minimize and mitigate the effects of the damage that does occur. Residents and governments at all levels have long recognized the need for flood protection and have been active in taking measures to safeguard businesses, homes, properties, and communities. These measures include construction and operation of reservoirs to contain floodwaters, levees and floodwalls to protect communities, and bypass channels to move the waters around critical areas; relocation of homes and businesses out of the floodplain; construction of agricultural levees and ring dikes around rural homes; use of agricultural practices that prevent rapid runoff; restoration of wetlands; preparation and updating of evacuation plans and flood forecasting and warning systems; and use of flood insurance to mitigate losses when they occur. Much more can and should be done to prepare for the variety of flood situations faced by the population of the Red River basin.

Table 2

Estimated Recurrence Intervals for the 1997 Red River Flood

Location	Estimated Recurrence Interval*	Chance of Being Equaled or Exceeded in Any Given Year
Wahpeton–Breckenridge	140-year	0.7%
Fargo–Moorhead	70-year	1.4%
Halstad	140-year	0.7%
Grand Forks–East Grand Forks	210-year	0.5%
Drayton	140-year	0.7%
Emerson	140-year	0.7%
Winnipeg	90-year	1.1%

* Estimates in the United States provided by the U.S. Army Corps of Engineers; estimates in Canada provided by Manitoba Conservation.

B. Flow Reduction Considerations

The Task Force and the Commission examined methods that might be considered for reducing the magnitude and timing of the flood flows. During its visits to the basin, the Commission found strong support for seeking methods of storing water in new reservoirs, on fields, or in restored wetlands, with many people noting that the natural and constructed reservoirs not only could reduce flooding but could also provide water storage during drought periods.

(1) Large Reservoir Storage

The record-breaking snowfall during the winter of 1996–1997, capped by a major blizzard in early April 1997, contributed the equivalent of 20 to 25 cm (8 to 10 inches) of water to the Red River basin for the 1997 flood. That equated to 25.9 million cubic decameters (dam^3) of water (21 million acre-feet) in the basin upstream of the confluence of the Assiniboine River. Of that amount, 11.1 million dam^3 (9 million acre-feet) ran off during the spring, while 14.8 million dam^3 (12 million acre-feet) remained on the land, slowly dissipating through

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U.S. Army Corps of Engineers, St. Paul District.

Aerial view of Baldhill Dam near Valley City, North Dakota.

evapo-transpiration, infiltration, and release to streams after the flood. To put this into perspective, the Task Force indicated that the five large U.S. flood control dams in the upper part of the basin (Baldhill, North Dakota; Homme, North Dakota; White Rock, Minnesota; Red Lake, Minnesota; and Orwell, Minnesota) provide over 1.2 million dam^3 (1.0 million acre-feet) of flood-control storage. In addition, another 280 water retention projects, developed for water conservation and other purposes, have a potential flood storage capacity of approximately 0.8 million dam^3 (0.7 million acre-feet). This latter figure is based on the difference between the maximum storage potential and the normal storage level and represents the amount of storage available at these structures, if water is at normal storage levels at the beginning of a flood. Holding back a portion of the peak flow can reduce flood damage and the risk of failure of flood protection works.

The Task Force examined the impact on downstream flood levels of "capturing" or holding back large volumes of floodwaters at various locations in the basin. Its analyses included: optimizing current flood control capacity; adding 856,000 dam^3 (694,000 acre-feet) flood storage in previously proposed but unbuilt reservoirs in the U.S. portion of the basin; and adding hypothetical storage volumes ranging from 123,000 to 986,000 dam^3 (100,000 to 800,000 acre-feet) in the United States.

Potential storage was then compared with the storage required to significantly reduce flood peaks. The Minnesota Department of Natural Resources conducted a simplified analysis to estimate the storage required to reduce the 1997 peak flow at Grand Forks to that of the smaller 1979 flood, that is, from 3880 cms (137,000 cfs) to 2520 cms (89,000 cfs). This reduction required approximately 1.6 million dam^3 (1.3 million acre-feet) of ungated flood storage immediately upstream of Grand Forks. Some have noted that if structures were gated, significantly less storage may be required. Modeling conducted by the Task Force found that if 986,000 dam^3 (800,000 acre-feet) storage were feasible between Grand Forks and Emerson, it could have reduced the 1997 flood levels at Winnipeg by up to 1.5 m (5 feet).

Economic, social, environmental and other considerations have prevented the construction of the U.S. reservoirs cited above to create an additional 856,000 dam^3 (694,000 acre-feet) of flood storage. No combination of sites has been identified to achieve the 1.6 million dam^3 (1.3 million acre-feet) of storage needed to reduce the flood at Grand Forks to the 1979 flood level, and it is unlikely that enough sites could be found that would be economically, socially and environmentally suitable. Therefore, reservoir storage can be only a part of a wider strategy to reduce the risk posed by major floods.

The Commission recognizes that large floods occur infrequently and that they are only one aspect of flood management in the basin. Overall flood management must consider large and small floods as well as spring and summer events. Increases in storage, or changes in reservoir operating plans, may prove effective in reducing the impact of smaller floods, and these options require further investigation. For example, most of the existing water retention projects in the basin are operated so that they are full at the end of the spring runoff. As such they can provide little or no flood protection during intense summer rainstorms. Operating these reservoirs at lower levels in the summer may provide unused flood storage at the cost of decreased water supply. Many of the dams that can store floodwaters temporarily would benefit immediately downstream agricultural or undeveloped areas, rather than more distant urban communities. The farther upstream a storage site is located, the fewer flood control benefits it typically provides. The Commission sees initiatives to reduce more frequent floods as complementary to the efforts to reduce damage from major floods and strongly supports continued efforts to alleviate the consequences of smaller floods. Local or regional initiatives should continue to be pursued, with full consideration of the net economic benefits and environmental impacts of such projects. The Commission concludes that:

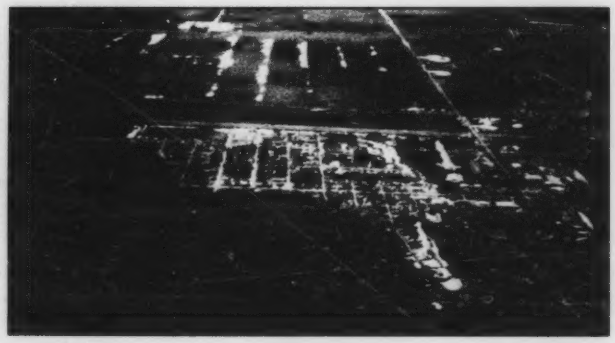
> **IJC Conclusion 2:** ***It would be difficult if not impossible to develop enough economically and environmentally acceptable large reservoir storage that alone would reduce substantially the flood peaks for major floods. Storage to reduce flood peaks for more frequent local floods may prove worthwhile and deserves further study.***

(2) Micro-storage

From the air, the network of section line roadways in the Red River basin looks like a waffle or an ice-cube tray. The visible lines are generally intersecting road surfaces that are higher than the adjacent lands. Culverts restrict the flow of water from these areas, thus providing some uncontrolled short-term micro-storage. This unintended storage has inspired proposals for a "waffle storage" solution: a basin-wide system to temporarily store floodwater using low relief fields bounded by existing or raised roadways. These pools could then be controlled actively by gates on road culverts or, in a passive system, by undersizing the road culverts to retard runoff. Both of these approaches envisage thousands of micro-storage sites scattered throughout the basin rather than the more conventional flood storage reservoirs discussed above. To be effective for large-volume floods, the stored floodwaters must reduce the peak on the Red River, not just on the tributary where the micro-storage is located. While any storage will reduce flow volume in the Red River, effective reduction of peak flows requires that releases be accomplished on a time-sequenced basis. This in turn requires accurate and detailed forecasts and a sophisticated control system for the micro-storage. Since micro-storage would retard runoff from agricultural lands, it would also increase the duration of flooding on these lands.

If the 1.6 million dam^3 (1.3 million acre-feet) of storage needed to reduce the 1997 flood flows at Grand Forks to 1979 flows came entirely from micro-storage, water would have to be stored to an average depth of 1 m (3 feet) on approximately 160,000 hectares (400,000 acres) of land, or about 1800 km^2 (700 square miles), all upstream from the point where the flood peak would be reduced. Because of storage inefficiencies and because local runoff conditions vary from year to year, achieving the desired flood control effect would require the commitment of well over 1800 km^2 (700 square miles) to micro-storage. Moreover, micro-storage would require many infrastructure changes. Roads would have to be raised and leveled and, in places, hardened, and culverts would have to be replaced or gated. The Task Force estimated the cost of such improvements would be at least U.S.$96,500 per square kilometer (U.S.$250,000 per square mile) or a total cost in the order of U.S.$175 million. In addition, there would be costs associated with annual operation and maintenance of the system, and requirements to compensate farmers when flooding delays or prevents planting. While these estimates of cost may be high, the Commission suggests that further investigation of associated costs based on local conditions should be pursued.

Micro-storage would also require the development and implementation of detailed plans for separately operating the gates that control water levels in each impoundment to reduce local agricultural flooding, and avoid the possibility of aggravating downstream flooding on the mainstem through inappropriate gate operation. Execution of these plans would require complex supervisory control and a data acquisition system working in conjunction with a fine-resolution distributed hydrologic model. If these problems could be solved, micro-storage could provide some benefits in reducing the impacts of smaller, more frequent floods and could contribute to an overall flow reduction effort for a large flood. The Commission concludes that:



U.S. Army Corps of Engineers, St. Paul District.

Raised roads near Drayton, North Dakota, capture floodwaters in a "waffle" pattern.

IJC Conclusion 3: ***Large-scale micro-storage has some potential to reduce flood peaks, perhaps significantly for more frequent local floods, but reliance solely on micro-storage for major flood events would be impracticable and costly. While there are many obstacles to its effective and efficient implementation, the feasibility of micro-storage for flood peak reduction should continue to be analyzed.***

(3) Wetlands

Wetlands serve many useful functions within prairie and riverine ecosystems. They influence flow regimes and water chemistry, contribute to groundwater supplies, and can modify the effects of floods and droughts. They also benefit wildlife and serve as valued habitat in regional and even continental ecosystems. From the early years of settlement, farmers were handicapped by wet land. Many areas of the Red River lowland were not continuously wet, but during years of heavy snowfall or more than average rain they were not fit for cultivation. These areas were an impediment to agricultural productivity. To support increased crop production, government programs encouraged wetland drainage. One study undertaken for the Task Force reconstructed the pre-agricultural landscape of the Canadian portion of the basin based on surveys in the 1870s. Wetlands comprised 12 percent of the landscape in 1870 but only 3 percent in 1995. Reliable figures on wetland drainage for the basin are not available, but it would appear that the vast majority of Red River valley wetlands were modified by human activity.

Depending on their structure and condition at the time of the flood event, wetlands may retain floodwaters and reduce peak flows or total flood volumes or both. Since little research has been done on this subject in the Red River basin, the Task Force undertook two studies that examined the potential for wetland storage to reduce flows on tributaries during major floods like that of 1997. The Task Force also examined the economics of increasing wetland storage. Based on these analyses, the Task Force concluded that a reduction of total flood volume is possible with expansion of wetlands, but large-scale wetland restoration programs do not appear to be an economically feasible way to reduce damage from major floods in the Red River floodplain.

The Commission notes that hydrologic analyses in other river basins have indicated that wetland storage can lower peak flows during smaller mainstem or tributary floods and minimally reduce the peaks of larger floods. Studies have also indicated that when larger areas are dedicated to wetland storage, the flood damage reduction and water quality improvements can be significant. The Commission notes that wetlands are frequently restored or constructed for their water quality and habitat values with little concern for flood control capabilities and are considered wise public investments. It may also be possible to farm restored wetlands during most growing seasons to minimize the economic impact on agriculture.[12] The more comprehensive potential environmental and social benefits that might accrue from preservation or restoration of wetlands deserve further investigation. The Commission concludes that:

> **IJC Conclusion 4:** ***Wetland storage can provide an economically and environmentally beneficial method of reducing flood flows for frequent, smaller floods, but wetland storage alone is unlikely to significantly reduce the peaks of large floods on the mainstem of the Red River.***

(4) Other Factors Affecting Flow

a) Drainage: Drainage of wetlands and agricultural and urban uses of land are often cited as factors that contributed to the record 1997 flood levels. Since artificial drainage moves water more quickly from where it accumulates to a natural watercourse, this appears reasonable. Changes in the time at which water enters a natural watercourse may, however, increase peak flows, cause no change, or even decrease the peak flows, depending on a number of factors. In 1997, record or near-record winter precipitation over most of the basin had saturated the ground, contributing to exceptionally heavy runoff that caused wetlands and other depressions in the land to fill and overflow. In addition, the peak flows on tributaries tended to coincide with peaks on the mainstem, thus exacerbating an already serious situation. The Task Force concluded that wetland drainage and land use practices contributed only a small amount, if any, to 1997 flooding. The significance of timing can be demonstrated by comparing the total flood volumes passing Winnipeg during the 1950 and 1997 floods. While the 1997 flood volume was similar to that of the 1950 flood, the peak of the 1997 flood at Winnipeg was substantially higher due to the coincidence in timing of the runoff throughout the basin. Removing water quickly from the land may provide a benefit in some years; in other years, it may mean that local peaks coincide with mainstem peaks and increase flooding. The Task Force was not able to examine in detail the impact of drainage on floods. This issue requires further study.

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[12] Correspondence from William J. Mitsch, Ph.D., Professor and Director, Olentangy River Wetland Research Park, The Ohio State University, Columbus, Ohio, October 3, 2000.

Barry Oswald, Manitoba Water Resources Branch

The ring dike surrounding St. Adolphe, Manitoba, holds back floodwaters, April 30, 1997.

b) Urban Levees: New urban levees for Grand Forks and East Grand Forks raised concerns about the effects on downstream water levels. The Task Force examined the impacts of the reduction in storage that would occur as a result of constructing higher levees to prevent flooding of the two cities and determined that the storage loss at the peak of major floods would be insignificant compared with the large volume of water in the Red River during these floods. The Commission concurs with this finding. Similar analyses will be required as part of the design of levee improvements elsewhere in the basin.

c) River Ice: Ice formation and accumulation in rivers can cause property damage, erode stream banks, disrupt transportation and hydropower operations, and make flood forecasting difficult. Ice jams occur frequently in the Red River basin and play a role in flooding on some tributaries and at a few locations on the mainstem. They can cause rapid and sometimes severe fluctuations in river levels and can alter the effectiveness of flood protection systems. While not a significant basin-wide factor in the 1997 flood event, ice remains a constant threat during spring melt at many locations. In 1996, a major ice jam resulted in flooding of portions of Selkirk, Manitoba. As the 1997 flood approached, drill holes were made in the ice near Selkirk to weaken the surface. In North Dakota, efforts were also undertaken to reduce ice jams by accelerating ice melting. No ice jam flooding occurred but the evidence is not conclusive as to whether this can be attributed to the drilling. Given the many unknowns in dealing with accumulating ice, mitigation strategies must be based on a thorough study of local conditions and take into account potential impacts on the environment and water quality, and the protection of downstream interests.

While some efforts have been made to catalogue ice jams, no basin-wide inventory exists. The U.S. Army Corps of Engineers' Cold Regions Research and Engineering Laboratory (CRREL) has developed a national ice jam database that contains a number of events in the U.S. portion of the Red River in which ice affected river stages. The Commission concurs with the Task Force that consideration should be given to incorporating all Red River basin ice jam information into the CRREL database so that ice problems in the basin can be further analyzed.

U S Army Corps of Engineers, St Paul District

Wild Rice River near Ada, Minnesota

C. Protecting Large Population Centers

As noted above, communities, in coordination with state, provincial and federal organizations, can protect themselves from flood damage by retaining runoff before it gets to the floodplain, moving water around communities through bypass channels, or removing structures from harm's way. Although these measures are effective in some circumstances, given the relatively flat terrain in the Red River basin, many communities have found levees to be the only economically justifiable and socially acceptable protection measure. Urban levees are appropriate protection, provided they are evaluated systemically, are set back a reasonable distance from the river, take account of natural functions of the floodplain, and do not affect upstream or downstream flood levels.

If structural improvements are not engineered to withstand the forces of flooding, or if the levees are not high enough or cannot be raised in an emergency to withstand expected flood levels, these systems may give residents a false sense of security. In some instances, all possible sources or pathways for flooding may not have been considered. These sources would include "backdoor" flooding, inadequately plugged sewer systems, unknown seepage paths under levees, inadequate closures at streets and railroads, and inadequate interior drainage. In addition, individual community projects must be evaluated systemically to determine their impacts on those outside the community and downstream and upstream from it.

The Commission considers it most important that those protected by levees understand that a residual flood risk remains even when permanent levees provide a high level of flood protection. Levee elevation design is based on protecting against floods of a certain height or frequency, taking into account the costs of levee construction weighed against the damage prevented. A flood that overtops the designed levee places the people and property behind the levee in jeopardy. The lower the level of protective structures, the more frequently the community is at risk. As part of flood preparedness, communities need contingency plans to deal with the possible overtopping or breaching of their levees.

Recognizing the catastrophic impact of the 1997 flood on Grand Forks, the staggering concentration of damage, and the impact that similar events could have on other large population centers in the basin, the Task Force, with financial support from the province of Manitoba and the city of Winnipeg, carried out an analysis of the flood threat to Winnipeg and developed possible approaches to dealing with this threat. The Task Force limited its review of the flood threat facing Fargo, Moorhead, Wahpeton, Breckenridge, Grand Forks, East Grand Forks and Selkirk to a reconnaissance-level examination. It did not undertake detailed studies of these communities. FEMA and the U.S. Army Corps of Engineers are conducting hydrologic and hydraulic analyses of the Red River in the United States, and the Corps of Engineers is currently completing detailed engineering studies for Grand Forks–East Grand Forks and Wahpeton–Breckenridge.

Edward Bailey, International Joint Commission.

Winnipeg Floodway inlet and control structure, May 18, 1997.

(1) Winnipeg: With a population of about 670,000, Winnipeg is the largest population center in the Red River basin. It suffered comparatively less damage from the 1997 flood than other cities in the basin, owing in large part to the substantial flood defense infrastructure that was constructed following the 1950 flood, coupled with an enormous human effort to raise dikes and to construct a 34-km (21-mile) extension to the west dyke. Prior to 1997, the flood defenses had performed well but the flood of 1997 stretched them to the limit. The defenses may be inadequate for the next flood of similar magnitude or larger unless they are significantly upgraded. To assess the vulnerability of the city, the Task Force, in collaboration with the province of Manitoba and the city of Winnipeg, reviewed the capacities and vulnerabilities of the flood protection system, examined new structural measures and operational changes, and conducted preliminary engineering feasibility studies of selected measures to increase protection.

Table 3

Capacities of Winnipeg Flood Protection System

Component	Design capacity		1997		Reliable capacity	
	cms	cfs	cms	cfs	cms	cfs
Shellmouth Reservoir	198	7,000	113	4,000	198	7,000
Portage Diversion	708	25,000	337	11,900	708	25,000
Winnipeg Floodway	1700	60,000	1900	67,100	2070	73,000
River Channel	2180	77,000	2260	80,000	2010	71,000
Totals	**4786**	**169,000**	**4610**	**163,000**	**Up to 4986**	**176,000**

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The 1997 flood produced flows through Winnipeg that exceeded the reliable capacity of its flood protection system (see Table 3). Nevertheless, the city survived with little flood damage, in part because of dry weather during the flood peak. This, however, provided a wake-up call for the city. The Task Force identified certain vulnerabilities of the current system. In high-priority areas where the consequences of failure would be severe, such as the overall system capacity, the Winnipeg Floodway inlet control structure, and Winnipeg Floodway embankments and dikes, additional investigations were undertaken. Lower priority areas were simply identified. Based on these analyses, the Commission concludes that:

> **IJC Conclusion 5:** ***Under flow conditions similar to those experienced in 1997, the risk of a failure of Winnipeg's flood protection infrastructure is high. Public safety requires that the city, province and Canadian federal government focus immediate attention on designing and implementing measures to further protect Winnipeg.***

There appears to be a general recognition that the current flood defenses of the city must be improved. That recognition must become reality through the design and implementation of appropriate measures. What level of flood can be expected and what level of protection is appropriate? The 1826 flood at Winnipeg, with a peak flow in the order of 6370 cms (225,000 cfs), approximately equivalent to a 1-in-300-year flood, is the largest flood on record. The Task Force estimated that a 1,000-year flood would have a flow of about 8490 cms (300,000 cfs). By comparison, the 1997 flood produced a natural flow through Winnipeg of 4620 cms (163,000 cfs), which is about a 1-in-90-year flood. Given that over 600,000 people could be at risk from an event larger than 1997, and recognizing the importance of the city to the provincial economy, higher levels of flood protection than currently exist must be provided. The Commission recommends that:

> **IJC Recommendation 2:** ***The design flood used as the standard for flood protection works for Winnipeg should be the highest that can be economically justified or, at a minimum, the flood of record, the 1826 flood.***

The Task Force detailed several options for providing an increased level of flood protection for the city. The Commission supports the two-step approach to flood protection for Winnipeg proposed by the Task Force. The first step would secure the city against the recurrence of a flood the size of 1997, and the second would provide an increased level of protection and security with full consideration of the social and environmental implications. As part of the first step, the Commission supports the need for improvements to the east embankment, west dike, primary dikes, and modifications to sewer and land drainage systems.

Pre-feasibility engineering studies identified, for further consideration under the second step, two major structural projects: expanding the existing Winnipeg Floodway and constructing a detention basin at Ste. Agathe. From an engineering perspective alone, these appear to have the greatest potential for providing the needed level of protection. From an economic perspective, initial cost estimates undertaken on behalf of the Task Force indicate that the Ste. Agathe detention project would likely be less costly to construct.

The Commission believes that construction of a detention structure at Ste. Agathe would have implications that go well beyond economics. The project raises very serious social implications, and the Commission believes its construction could adversely affect future development in the region. During its public hearings in February 1998 and May 2000, the Commission heard at first hand the concerns and frustrations of residents upstream of the Winnipeg Floodway and from those who could suffer increased flooding from 100-year events or larger as a result of the proposed Ste. Agathe detention structure. The method of operation of the Winnipeg Floodway was a major concern in 1997, when residents upstream of the Winnipeg Floodway suffered increased flooding as a result of an operating rule that was implemented to provide an increased level of protection to the city. Many residents were troubled by what they perceived as a lack of concern on the part of Winnipeg residents and the operators of the Winnipeg Floodway about what happened outside the perimeter of the city. It was suggested that this perception was reinforced by Winnipeg's publicly manifested view that the crisis as a whole was over once the safety of the city was assured. The Commission agrees with the sentiments expressed by residents upstream of the Winnipeg Floodway that they received neither adequate recognition for the disruption to their lives, nor full and prompt compensation for their losses.

The 500 or more people who attended the Commission's May 2000 hearings at Winnipeg and Emerson reflected the level of public concern over the proposed Ste. Agathe structure. At these hearings, the Commission heard many presentations opposing the structure. Speakers suggested that the Ste. Agathe detention structure would prove to be more expensive than expanding the Winnipeg Floodway when flood easement costs, compensation costs and lost revenues from the rich agricultural land in the area were included. They questioned whether such a structure could be acceptable from an environmental standpoint, and whether upstream communities could be protected by higher ring dikes. They pointed to the social costs of demoralizing a region, pitting those in rural areas against Winnipeg residents, and deterring development by intentionally making the region more vulnerable to floods. The Winnipeg Floodway, they said, had been designed so as not to flood unduly those who are not protected by the system. This approach should also be taken in providing protection for the city against a flood greater than the one that occurred in 1997. They were adamant that they should not be willfully sacrificed for the protection of the city. The Commission fully shares this view.

Clearly, the protection of Winnipeg must be given a high priority. But it is equally clear that proposals for additional flood protection for the city or alterations to the operating rules for the Winnipeg Floodway must take account of the full economic, social and human costs for other areas that would be affected by such measures. A transparent process of open consultation must be established to ensure that residents of such areas have an opportunity to be an integral part of any decision-making process. The Commission considers that the doubts expressed about the efficacy of a detention structure at Ste. Agathe as the solution to Winnipeg's flood problems must be addressed and that there must be a full evaluation of the economic and social costs of the projects proposed. If the consensus is to proceed with such proposals, prompt and complete compensation of damages should be provided to any who are injured as a result. It is noteworthy that the Boundary Waters Treaty would provide for adequate protection and indemnity to persons in the United States who might be injured by an increase in water levels caused by a structure such as that proposed at Ste. Agathe. It is hard to imagine that Canadians should receive less consideration.

The Commission recommends that:

> **IJC Recommendation 3:** ***The city, province and the Canadian federal government should cooperatively develop and finance a long-term flood protection plan for the city that fully considers all social, environmental and human effects of any proposed flood protection measures and respects both the needs of Winnipeg and the interests of those outside the city who might be affected by such a plan.***

In response to suggestions made by the public in 1998, the Task Force investigated two proposals for increasing the discharge capacity of the Winnipeg Floodway channel—removal of the outlet structure and removal of the inlet weir or plug. Analysis shows that removing the outlet structure could produce a minor increase in flow capacity of 56.6 cms (2,000 cfs) and result in significant erosion. Removal therefore cannot be justified. Lowering the inlet weir crest level by 2.13 m (7 feet) to the level of the Winnipeg Floodway channel would increase the discharge capacity by 1.4 cms (50 cfs). This benefit is insignificant and not worth the complications arising from early entry of ice into the Winnipeg Floodway channel. The Commission concludes that neither of these options should be given further consideration.

In addition to structural measures, there are a number of non-structural protective measures that need to be addressed by the city of Winnipeg. Despite the success of efforts in 1997, more planning for extreme events must be undertaken. The Commission encourages the city to enhance the flooding component of its Emergency Preparedness and Response Plan (EPRP) to address the following:

- emergency evacuation of large portions of Winnipeg;
- emergency response to breaches in flood-retaining structures;
- emergency construction of approximately 80 km (50 miles) of temporary dikes; and
- planning for operation of flood control works during unprecedented flow conditions.

Current efforts to assemble and document emergency procedures should be expanded, with high priority being given to the preparation of a detailed emergency preparedness and response manual. Other prudent measures should also be undertaken including correcting sewer cross-connections, improving the land drainage system, and data acquisition and modeling to enable enhancement of the city's flood preparedness.

(2) Fargo–Moorhead: Fargo is protected by a permanent levee and bypass channel flood control project which was completed in 1961, and by the west Fargo diversion, substantially completed in 1993. Prior to the 1997 flood, the 100-year flood level was estimated to be 11.7 m (38.3 feet). The top of the permanent levees in Fargo is at 12.2 m (40.0 feet), after settling 0.4 m (1.3 feet) from original construction. A record-setting flood crest elevation occurred in 1997 at 12.1 m (39.7 feet). Following the 1997 flood, the recurrence interval for this flood was estimated to be 70 years. Moorhead, on the other hand, has no permanent federal flood control project. Although the design height of permanent flood control projects was exceeded during the 1997 event, both communities avoided major flooding in 1997 by either raising existing levees or building temporary barriers.

Since the 1997 flood, both communities have implemented mitigation measures, including the acquisition of almost 100 floodplain homes, raising and stabilizing existing levees, installing permanent pump stations, and improving storm sewer lift stations and the sanitary sewer system. The city of Fargo is investigating the feasibility of providing permanent protection to areas on the south side of the city that are currently unprotected. Most of the levees built since the 1997 flood are eligible for inclusion in the U.S. Non-Federal Flood Control Works Inspection Program but have not been certified by the Federal Emergency Management Agency (FEMA) as providing 100-year flood protection.

As mentioned previously, the hydraulic model developed to simulate one scenario that would yield the record 1826 flood discharges experienced in Winnipeg shows Red River flood levels at Fargo–Moorhead reaching approximately 13.0 m (42.5 feet), more than 0.8 m (2.5 feet) higher than the level experienced in 1997. Following completion of the Task Force's report, the U.S. Army Corps of Engineers, under contract to FEMA, completed a new flood frequency analysis for the Fargo and Moorhead area. The results indicate that the volume of water running through Fargo and Moorhead in a 100-year Red River flood would be 8 percent greater than previously thought. This increase, in combination with new hydraulic analyses, would raise the 100-year flood elevation by approximately 0.8 m (2.5 feet) to 12.4 m (40.8 feet).

Since the flood of 1997, the residents of Fargo and Moorhead have been hit by several major storms that have caused significant flooding within the two cities. While most of the damage that has occurred can be attributed to the inability of the existing interior drainage systems to quickly carry away runoff from the storm, there is a close relationship between actions needed to deal with these local floods and those required for floods on the Red River. During and following public hearings, the Commission was told that measures aimed at small and local floods would also help Fargo and Moorhead deal with large floods.

It was said that any reduction in 1997 would have been welcome, and that measures to deal with smaller, more frequent floods needed to be addressed. Speakers also regretted that there had not been more analysis of the flooding potential of the two communities. The Commission notes that the Task Force's efforts were focused on the 1997 flood and recognizes that little analysis was made of the specific needs of Fargo and Moorhead.

Fargo and Moorhead face a difficult situation. They are now dealing with two new assessments of large floods (the new 100-year flood level and the possible 1826 level) that indicate flood risks greater than previously thought, and there appears to be significant disagreement about both the determination of flood levels and the actions that should be taken to prevent future damage. Both communities believe that mitigation actions must be taken within the context of a basin plan and must include reduction of flood flows, strengthening of existing protection structures and use of other flood damage reduction techniques. The Commission concurs with this approach. It also understands that Fargo and Moorhead have requested the U.S. Army Corps of Engineers and FEMA to determine more accurately the threat to their communities. Until this work is carried out and solutions aimed at reducing the determined flood risks are developed, Fargo and Moorhead remain at undue risk. The Commission recommends that:

> **IJC Recommendation 4:** ***The government of the United States, in cooperation with the cities of Fargo and Moorhead and the states of North Dakota and Minnesota, should expedite the study of flood risk potential and implement plans for flood protection measures for the Fargo–Moorhead area.***

(3) Grand Forks–East Grand Forks: At Grand Forks and East Grand Forks, the maximum 1997 flood level on the Red River was 16.56 m (54.35 feet) and was estimated to be a 210-year event. Temporary levees built to levels of 15.8 to 16 m (52.0 to 52.5 feet) were overtopped. The resultant damages to the cities of Grand Forks and East Grand Forks were estimated to be U.S.$3.6 billion. Since the flood, the communities have worked with the U.S. Army Corps of Engineers to develop and implement an appropriate protection strategy. After consideration of several alternative approaches, including use of a bypass channel, the Corps and the communities decided on a plan that raises portions of the existing levee system, sets back and strengthens other portions, and constructs floodwalls in other areas. To accommodate the setback and to reduce the number of homes and businesses at risk, over 1,000 structures have been or will be removed from the floodplain. This U.S.$350.3-million project is underway and is scheduled for completion by 2006. The project is designed to provide permanent protection from the 210-year flood event, with 1 m (3 feet) of freeboard provided above the 210-year flood level. As part of the overall flood protection plan, a permanent "invisible" flood wall providing the same level of protection to downtown East Grand Forks is now complete. Pending completion of the permanent structures, both communities have taken interim measures, including the raising and stabilizing of temporary levees and improving storm and sanitary sewer

Eric Hylden. Used with permission of the *Grand Forks Herald*

View of Grand Forks, North Dakota.

systems. The hydraulic model developed to simulate one scenario that would yield the record 1826 flood discharges experienced in Winnipeg shows Red River flood levels at Grand Forks–East Grand Forks reaching approximately 17.4 m (57.0 feet), more than 0.8 m (2.6 feet) higher than the level experienced in 1997. Given that the design level of protection for the permanent flood protection structures for Grand Forks and East Grand Forks is equal only to the 1997 flood, the Commission cautions that the proposed level of protection must be periodically evaluated to ensure that it remains adequate in the face of changing conditions throughout the basin. The Commission strongly supports the inclusion of flood-proofing measures for new buildings in areas that would be protected by the new levees. The Commission recommends that:

IJC Recommendation 5: ***The government of the United States, in cooperation with the cities of Grand Forks and East Grand Forks and the states of North Dakota and Minnesota, should ensure that the planned flood protection works are promptly and expeditiously completed.***

(4) Wahpeton–Breckenridge: In the Wahpeton–Breckenridge area, the 1997 flood reached a level of 5.9 m (19.42 feet). It came within inches of overtopping the emergency levee that had been built to contain the flood at Wahpeton, but the community was not flooded. During the summer and fall of 1997, Wahpeton began construction of permanent levees on its own, but a shortage of funds ended the project before completion, with protection provided only for the south side of the city. Breckenridge's levees were overtopped twice during the 1997 flood, first from the north and then from the south, flooding most of the community and causing damages of U.S.$30 million. Breckenridge has undertaken a number of flood damage reduction measures since the flood, including removing damaged homes from the floodplain, installing pumping stations, and building levees, and continues to work toward improving the city's flood protection. In response to a request from Wahpeton and Breckenridge, the U.S. Army Corps of Engineers has undertaken flood reduction feasibility studies and is developing multi-featured flood reduction projects for both cities at an estimated cost of U.S.$9.5 million for Wahpeton and U.S.$20.5 million for Breckenridge. The Wahpeton and Breckenridge projects will provide 125-year flood protection by raising the top of their levees to 6.6 m (21.8 feet) at the U.S. Geological Survey gauge. The Breckenridge project also includes a diversion of the Ottertail River flows around the community and into the Red River. The hydraulic model developed to simulate one scenario that would yield the record 1826 flood discharges experienced in Winnipeg shows Red River flood levels at Wahpeton–Breckenridge reaching approximately 6.2 m (20.3 feet), more than a third of a meter (one foot) higher than the level experienced in 1997. With the flood reduction projects for the communities yet to be completed, these communities remain at undue risk. The Commission recommends that:

> **IJC Recommendation 6:** ***The government of the United States, in cooperation with the cities of Wahpeton and Breckenridge and the states of North Dakota and Minnesota, should expedite approval and implementation of flood protection plans to reduce the risk of flooding at Wahpeton–Breckenridge.***

(5) Selkirk: The city of Selkirk is located on the Red River north of Winnipeg. It has experienced flooding of waterfront properties and outfalls of the storm water sewer system on numerous occasions in the past. One of the major concerns in the area is ice jamming in the river, which, in 1996, caused levels higher than the flood of 1997. Although the risk of flooding in the city of Selkirk was not examined by the Task Force under its study plan, Red River flows greater than those of 1997 would pose a threat to the city. Prior to the 1997 flood, Selkirk was believed to be protected against the 160-year flood. Analysis following the flood revealed that the present level of protection is likely closer to the 100-year flood level. Thus, there is an immediate need to quantify areas at risk, develop mitigation measures, and increase the level of protection to avoid future flood damage in the Selkirk area. Moreover, downstream impacts on Selkirk must be considered in the development of additional flood protection works for Winnipeg. The Commission recommends that:

> **IJC Recommendation 7:** ***The province of Manitoba and city of Selkirk should expedite studies of flood-risk potential in the Selkirk area.***

D. The Impacts of Flooding

The economic toll of the 1997 flood is still being determined on both sides of the border. Homes and businesses were damaged and destroyed. People were kept away from their homes, businesses and stores for months, if not forever. Seeding was delayed and in some cases farmsteads were destroyed by the floodwaters. The estimate of the total economic damages sustained in the basin approached U.S.$5 billion. The impact of the damage primarily fell on those who lived in the flood's path. The human impacts of the flooding have been difficult to measure. Many people who were forced from their homes, as the floodwaters rose, came back to find everything they owned destroyed, which meant long periods living with friends, in government-provided trailers or in other temporary accommodations. Those who could return to their homes found them filled with muck,

It is very difficult to be objective or unemotional when relating the pain and uncertainty of our lives over the last 10 months. The effect of dislocation, the loss of place, cherished possessions and the ensuing anxiety over disruption in children's development and security, stress on marriages, damage to livelihoods and cost of rebuilding is extremely hard to describe. The emotional gamut for us has run from despair to anger, dismay to worry, acceptance to determination.

Floodplain resident, IJC public hearing, Ste. Agathe, February 12, 1998 their family treasures saturated by the muddy waters, and their health at risk from molds. Farmers and store owners faced similar challenges. Their ability to survive economically was in question. For a period, few thought Grand Forks and East Grand Forks could recover, and many in Grand Forks, East Grand Forks and the surrounding flooded countryside considered leaving the area permanently.

With the support of governments at all levels and many non-governmental and voluntary organizations, recovery has, for the most part, taken place. But it was not easy. For months, and in some cases years, people did not know where to go or what to do. If they planned to rebuild or repair, they were unable to determine the conditions under which they would be able to do so. Would they be able to rebuild in the same place? At what elevation should a new home be built? How would the proposed solutions to the flood problem in the major cities affect those outside the flood defenses? If another flood occurred, would they be inundated again? Many of these questions remain unanswered and those affected struggle to continue their lives with this uncertainty.

There is no satisfactory way to sum up the collective trauma of the over 100,000 people who were affected by the flood and who struggle to recover, even now, more than three years after the event. The Commission knows from its many visits with local residents, public hearings, and study of the flood that the human toll is high and is real. There is no easy way to assign an economic benefit to the value of knowing one is relatively safe from future floods or the economic cost of the trauma of knowing that you may once again be flooded. Uncertainty about the amount and timing of compensation from governments still are important issues in many people's minds. Many residents upstream of the Winnipeg Floodway who were harmed by increased water levels caused by the way in which the Winnipeg Floodway was operated to save Winnipeg feel that the matter still has not been satisfactorily addressed by the government of Manitoba.

Prairie Farm Rehabilitation Administration

The 1997 flood inundated Ste. Agathe, Manitoba.

The Task Force commissioned a review of available literature and research on the human costs of enduring and coping with the flood, flood recovery and dealing with an uncertain future.[13] This work provided the basis for the findings noted in the box insert on page 37.

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[13] Natural Hazards Center, University of Colorado, *Evaluation of a Literature Review of the Social Impacts of the 1997 Red River Valley Flood* (October 1999). (Available at: www.ijc.org)

The Commission finds that this research is supported by the anecdotal evidence it has obtained during the study and strongly supports the continuation and extension of such investigations and analyses. The Commission recommends that:

> **IJC Recommendation 8:** ***To improve resiliency in the basin, governments should support enhanced research into the various social dimensions of the flood, including economic, psychological, public health and sociological impacts.***

E. Resilience

The residents of the Red River basin must be ready to cope with the next flood. They must be prepared to deal with the challenges of fighting the flood and flood recovery. In other words, they must become resilient to the effects of flooding where they cannot avoid them. The Task Force defined resilience as the ability to bounce back or adapt quickly to the consequences of an extreme natural event, such as a flood. It found that resilience is developed through many measures that reduce the effects of future floods. These measures include accurate and timely warnings, flood control measures, the designation of flood-prone areas as open space, flood insurance, flood-resistant construction, and storm-water management. Flood insurance and its role in improving community resiliency is discussed later in this report. Even with the adoption of structural projects that will reduce flood flows or provide direct protection against floods, many communities and residents will still remain at high risk from major floods. The Task Force outlined non-structural measures that communities can take to help reduce the impact of flooding and give residents the ability to adapt quickly to the consequences of floods. The Task Force also recommended that governments monitor indicators of resilience, such as the extent to which the floodplain is occupied and the number of insured households, since monitoring such factors would not only help identify problems and deficiencies in individual and community resilience, but would also help establish a baseline against which progress can be measured. The Commission strongly supports the Task Force's recommendations that call for effective strategies to improve disaster resiliency in basin communities, and development of flood resilience measures and of the means to monitor resilience in the Red River basin.

The Human Costs of Floods

The flood had a disproportionate impact on women.

In Grand Forks, flood damaged businesses owned or managed by women were twice as likely to remain closed as were others.

Women in the United States were at increased risk of domestic violence after the flood.

Stereotypical gender patterns became more prominent after the flood, to the detriment of women.

The stress to residents in the flooded and evacuated areas of Manitoba was increased by their inability to access timely, relevant flood-warning, evacuation, and recovery information from governments.

The flood tested marital relationships.

Racial and cultural bias was evident in some aspects of recovery in the United States.

A majority (65 percent) of social practitioners dealing with juveniles, the family, mental health, and gerontology in Greater Grand Forks said that their clients were unsettled by the flood.

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F. Individual Homes, Small Communities, and Agricultural Areas

Flooding problems in the Red River basin are widespread. Communities of all sizes are affected, as are individual homes, farmsteads and agricultural lands. The flood of 1997 highlighted the need for governments, communities and residents in the valley to actively pursue measures to further safeguard businesses, homes, properties and communities. While many had some level of protection, their protection in many cases was insufficient to withstand the floodwaters of 1997. The Task Force outlined many programs under which flood protection works are being improved, as well as many of the local community protection measures that are currently being assessed or are under construction. The level of effort currently underway to enhance protection throughout the valley is a testament to the respect that many have gained for the river.

Edward Bailey, International Joint Commission.

Ring-diked homes south of Winnipeg. The 1997 flood spared some but inundated others.

Local protection projects must be evaluated systematically, taking into consideration the potential force and direction of floodwaters, seepage and drainage of trapped waters, the natural functions of the floodplain, and the impact of the project on other areas. When structural measures such as levees or ring dikes are the selected option, some risk of failure or overtopping by an extreme event must be considered and appropriate contingency plans must be developed and maintained. Structural protection measures must be designed and constructed to recognized standards. Otherwise, a false sense of security may develop. In the U.S. portion of the basin, levees in 70 percent of the communities do not meet minimum federal standards and have not been approved under the U.S. Non-Federal Flood Control Works Inspection Program. While this does not necessarily mean that they are inadequate, their structural integrity should be reviewed as many of the levees were built under less than ideal weather conditions, during an emergency situation, and possibly without adequate engineering. The Commission supports the Task Force's recommendation calling for community-built flood damage reduction projects in the United States to be certified by FEMA as providing 100-year or greater flood protection, or to be approved under the U.S. Non-Federal Flood Control Works Inspection Program if less than 100-year flood protection is provided.

Emergency plans in all communities in the basin are fundamental for effective flood preparation, response and recovery. These plans should be reviewed regularly and adjusted in the light of past experience and lessons learned from other communities. Where innovations have proven effective, they should form part of the revised plan. The Commission reiterates the recommendation made in the Task Force's interim report that flood emergency plans for all communities within the basin be reviewed and updated based on lessons learned during 1997.

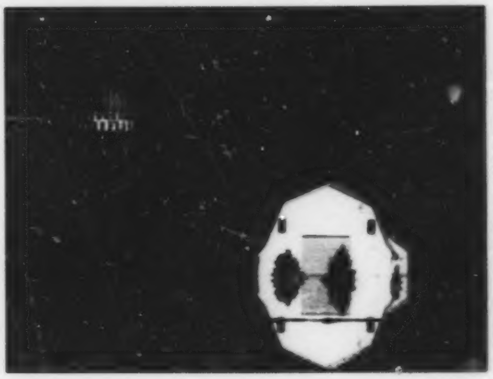
Photo by Michael M. Miller, NDSU Libraries, Fargo, ND

The 1997 flood inundates a farm in the upstream portion of the Red River basin.

In the United States, flood protection projects for small communities, individual homes, and farmsteads often cannot meet the benefit-cost criteria for obtaining federal funding, leaving them to rely on whatever state, local, or private initiatives and funding may be available. In Manitoba, over Can$44 million was made available under a federal-provincial program for moving, raising or diking individual homes, properties and businesses, while up to Can$60,000 in assistance was available for individual claims. A total of Can$380 million has been paid out in damage claims and for flood fighting efforts. In the United States, as of September 30, 1997, FEMA had provided over U.S.$145 million in individual assistance, over U.S.$39 million in hazard mitigation assistance, and over U.S.$134 million for flood insurance claims, while the Small Business Administration had provided nearly U.S.$169 million in home loans.[14]

The Task Force suggested that it is not generally economical to protect agricultural land against spring floods in the Red River basin, noting that they often do less damage to crops than floods during the summer growing season. During public hearings, however, several individuals stated that there is a substantial reduction in yield for every day that seeding is delayed. Others stated that the impact of flooding on agriculture should have been given more attention in the study. The Task Force did not address agricultural issues as it understood that crop losses due to the 1997 flood were minimal. It also noted that while locally funded agricultural levees provide some flood protection, typically for smaller, more frequent flood events, the impact of such levees on other areas in the basin has generally not been evaluated but should be considered in taking a basin-wide approach to flood mitigation.

> **IJC Recommendation 9:** ***Governments at all levels should ensure that in the development of flood mitigation strategies for the basin the needs of small communities, individual isolated farmsteads and agriculture are not overlooked.***

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[14] *Final Report of the President's Long-term Recovery Task Force. Minnesota. North Dakota. South Dakota* (December 1997).

Edward Bailey, International Joint Commission

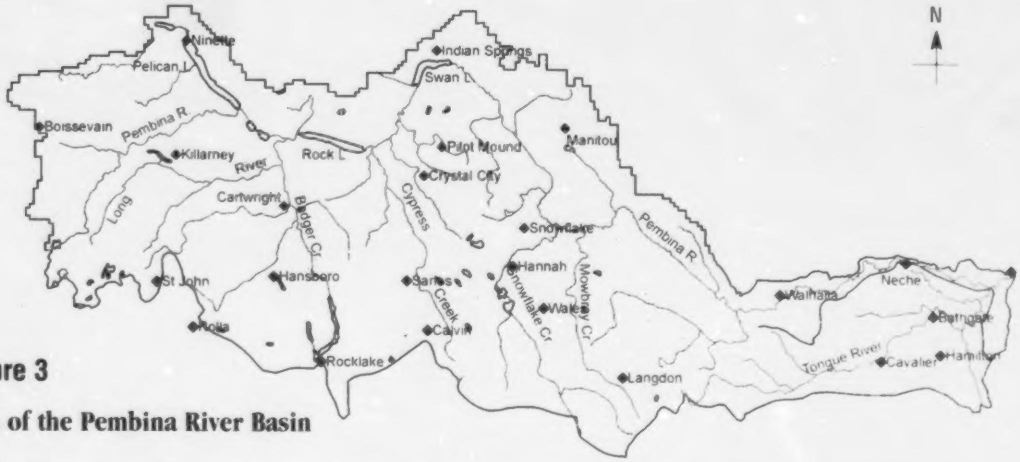
Highway #75 south of Winnipeg. Flooding of highways throughout the basin disrupted transportation.

G. Transportation Corridors (Roads, Railroads, Bridges)

Major floods often disrupt transportation. This was certainly the case in 1997, when the primary north-south highway corridor (Interstate 29 and Provincial Trunk Highway 75) and the main east-west corridor (US 2) were closed. Regional and local roads were flooded and bridges were closed over the Red River between Fargo and Winnipeg, a distance of over 320 km (200 miles). Primary railroad lines were also under water, requiring the re-routing of rail traffic. Because of the flat terrain throughout most of the Red River valley, roads and railroads will continue to be flooded by major events like that of 1997. One solution to this problem is to raise major transportation routes to reduce the frequency of their flooding. In the flat terrain of the Red River valley, such construction can, however, have unintended effects by retaining or redirecting floodwaters when they break out of the river channel. The raising of any road or rail lines must anticipate possible hydraulic impacts and hydraulic modelers in the basin must be informed of the location of any proposed or actual changes, so that their significance to future flooding can be determined.

H. Pembina River

Spring floods are a natural and common occurrence along the Pembina River, a tributary to the Red River located along the Canada–U.S. boundary. A map of the Pembina River basin is shown in Figure 3. The most significant flooding occurs along the 56.4-km (35-mile) reach between the Pembina Escarpment at Walhalla and the Red River. For more than 50 years, unilateral dike and road building along both sides of the border has been the source of transboundary disputes and tension. Over the years, federal, state, provincial and local governments have undertaken a number of initiatives to find solutions to the problems of transboundary flood management, but none have succeeded. The Task Force provided a common base of information to assist governments and local interests in resolving the issues. It developed detailed mapping of the lower basin and a computer model to simulate various topographic configurations and river flow conditions. The Task Force used the models to test approaches to flooding and flood protection. The resulting flow patterns from each scenario provide a basis for discussion and consideration of options for resolving the flooding problems. Unfortunately, time and resource constraints prevented the Task Force from pursuing the matter to completion.


N
Ninette
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Boissevain
Pembina R
Killarney
River
Rock L
Pilot Mound
Manitou
Crystal City
Cartwright
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Badger Cr
Cypress
Snowflake
Pembina R
Hannah
St John
Hansboro
Sarles
Creek
Snowflake Cr
Mowbray Cr
Walhalla
Neche
Wales
Rolla
Calvin
Bathgate
Rocklake
Langdon
Tongue River
Cavalier
Hamilton

Figure 3

Map of the Pembina River Basin

Wes Peck, Energy and Envirnomental Research Center, University of North Dakota

The Task Force worked closely with the Pembina River Basin Advisory Board in defining various scenarios and has shared the outcome of the studies with them. The Pembina River Basin Advisory Board serves as a valuable forum for the public presentation and discussion of new information on water management and has indicated its interest in pursuing a resolution of the long-standing Pembina issue. There appears to be a general readiness at the local level to resolve the issue, and this opportunity should not be lost.

The Commission has recently been informed of new developments in the United States involving a decision of the North Dakota Supreme Court that upholds orders for the removal of certain illegal dikes along the Pembina River. This development again brings out the evolving nature and difficulty of this issue. The Commission considers that resolution of this transboundary flooding issue will require a commitment of time and resources by government agencies in both countries. The Commission agrees with the Task Force recommendations calling for federal involvement in the process, the modeling of proposed physical changes prior to implementing any plan, and continuing work on the virtual database and decision-support system prototype. The Commission calls on governments to establish a consultative group to work with local interests and encourages governments to commit the necessary resources to resolve the issue. The Commission recommends that:

> **Recommendation 10:** ***Federal government agencies, in cooperation with the state of North Dakota and the province of Manitoba, should establish a consultative group to work with local interests, including the Pembina River Basin Advisory Board, to resolve the lower Pembina River flooding issue, provide necessary resources for the group, and act to achieve a solution.***

I. Flood Preparedness and Mitigation

Residents of the Red River valley have a right to expect that governments at all levels will show leadership and provide guidance in the development and implementation of mitigation measures, including sustained actions to reduce or eliminate long-term risk from flooding and its effects. Canada and the United States differ in their approach to flood preparedness. The United States has a framework for dealing with issues through the National Flood Insurance Program (NFIP), mitigation initiatives under the Robert T. Stafford Disaster Relief and Emergency Assistance Act, and a national mitigation strategy. The Canadian approach is less integrated and tends to be event-driven, with no common programs or frameworks tying activities together. Because of the frequency and magnitude of floods in the Red River basin, it is essential that flood preparedness and mitigation activities become a central focus of comprehensive, integrated basin management.

Unfortunately, mitigation activities receive very little attention except during times of crisis and for a short time thereafter. Ideally, planning and coordination leading to an integrated approach to mitigation must take place on a continuing basis during non-crisis periods so that projects are coordinated, potential impacts are considered, and funds are spent wisely. This had not been the case in the Red River basin. A sense of complacency had set in, government funds for monitoring and environmental work had been cut back, and priorities had shifted to other matters. The 1997 disaster presented an opportunity to rethink mitigation activities as funding was made available from a number of sources, and the will to act was present. The difficulty will be to maintain this interest and government support over the longer term to ensure that lessons learned from the event are carried forward and appropriate basin-wide preparedness and mitigation plans are developed and implemented.

The Commission endorses the Task Force's recommendations regarding the need for an overarching framework for mitigation:

> **IJC Recommendation 11:** ***Governments should develop a binational integrated approach to mitigation initiatives at all political levels, based on a comprehensive mitigation strategy for the entire basin. In the United States, the strategy should be integrated within the overall national framework.***
>
> **IJC Recommendation 12:** ***The Canadian federal government should establish a national flood mitigation strategy, or a broader disaster mitigation strategy, and support it with comprehensive mitigation programs.***

The Task Force addressed numerous elements of mitigation, including building standards, education, enforcement, floodplain acquisition, and flood insurance. It also encouraged the sharing of information about recovery and rebuilding techniques specific to the Red River basin. These are all elements of a flood mitigation strategy and are essential to reducing the risk of flooding in the basin.

For communities and residents to take responsibility for flood protection, they need to understand where the water will flow under different flood conditions and appreciate their level of flood risk. Efforts need to be made to increase public awareness of flood risks throughout the basin, including for locations that are structurally protected from floods, so that appropriate decisions will be taken to make developing communities resilient to flooding. Initiatives such as FEMA's Project Impact and its transboundary pilot project in the Red River basin, the International Flood Mitigation Initiative, are promising steps aimed at improving resilience to floods.

Within the Canadian and U.S. portions of the Red River basin, the governments have their own policies and regulatory measures for defining flood-prone areas, and each has designated an official or regulatory Red River floodplain. Following the 1997 flood, the Task Force and others developed new data, tools and techniques to improve floodplain definition. The Commission recommends that:

> **IJC Recommendation 13:** ***Governments should use, at a minimum, the 100-year (1 percent) flood as the basis for floodplain regulations and revise their estimates of the 100-year flood levels based on 1997 and new data that become available.***

The Commission notes that Manitoba has specified more stringent floodplain management standards based on historical flood levels. The Commission believes that consideration must be given to greater than 100-year flood protection when the expected impacts of such larger floods are unacceptable. The Commission thus concurs with the Task Force's recommendation to use the 500-year (0.2 percent) flood to inform the public of potential risks of flooding from rare events and as the basis of regulations for siting and flood-proofing critical facilities.

Although regulations in both countries require that new, and in many instances, improved, structures located in the floodplain be elevated to certain levels or protected from floodwaters by other means, the 1997 experience, once again, points to the need for improved enforcement of measures to reduce the impact of such flooding. Lack of enforcement at the local, state or provincial levels of floodplain regulations, zoning bylaws and ordinances resulted in significantly higher damages than would have occurred with more effective enforcement. The Task Force also reviewed building codes and standards for flood hazard areas. Current practices vary throughout the basin and greater attention to this issue is needed to support enhanced floodplain management and flood damage reduction. In order to achieve successful flood damage reduction programs, it will be necessary to fully integrate building codes and land use restrictions into floodplain management regulations. The Commission endorses the Task Force's recommendation regarding enforcement of building codes, zoning and other regulatory measures. These are only as effective as their enforcement.

> **IJC Recommendation 14:** ***State, provincial and other appropriate authorities should review the effectiveness of and compliance with the floodplain management regulations in the basin and take steps as needed to improve enforcement.***

Buyouts and removal of flood-damaged buildings reduce future flood losses and help build resilience, but only if the land remains permanently vacant. The Task Force questioned prohibitions on the siting of flood control levees on land that was acquired through FEMA's Hazard Mitigation Grant Program. The Commission notes that FEMA and the U.S. Army Corps of Engineers signed a Memorandum of Agreement regarding this issue on March 29, 2000; thus, the Commission believes there is no need for further comment. In the United States, buyout programs proved effective following the 1997 flood and many structures were removed from flood-prone areas through voluntary sales. The Commission encourages Canadian jurisdictions to review this practice and to implement programs of a similar nature to reduce the severity of future flood losses in Canada.

The Task Force described aspects of the U.S. National Flood Insurance Program (NFIP). Flood insurance can be a positive force, promoting flood preparedness, sustainability and resiliency, and it can be a highly effective mechanism for fostering individual responsibility by spreading the cost of flood damage among those who bear the risk. The Task Force discussed incentives and disincentives to purchasing flood insurance. The Commission also heard concerns expressed about certain aspects of flood insurance and insurance coverage. These concerns included allowing basements to be constructed under certain conditions, yet not covering basement contents, and making more than emergency disaster assistance funds available to those who were eligible for but who did not purchase flood insurance.

Under the NFIP, administered through FEMA, flood insurance is made available to residents of communities if and only if the community adopts and enforces floodplain management regulations. New or substantially improved buildings in the regulatory floodplain must be constructed so that the lowest floor, including basement, is at or above the 100-year flood level. Flood insurance for these new or improved buildings is actuarially rated (i.e., based on the actual risk involved).

Under some circumstances, FEMA will grant an exception to a community to allow floodproofed basements if the community adopts an ordinance that specifically controls how basements are constructed and used. Such exceptions have been issued for several communities in the Red River basin. FEMA conducted an assessment of 111 floodproofed basements constructed in these communities and found only a single failure: the basement floated.[15] Considerable damage occurred to many basements in the Red River basin not constructed to the flood-proofing standards, particularly where the basement areas had been finished for use as living spaces. FEMA recently conducted a study[16] to determine whether it should provide coverage for personal property in basements but determined that the cost would be prohibitive for the consuming public.[17]

While money is often made available in the United States following a presidentially declared disaster to those without flood insurance, and was made available after the 1997 flood, it is usually a loan which must be repaid or a means-tested grant. No repayment is expected for flood insurance claims payments. While property may be bought out even when not covered by insurance, these properties cannot be readily identified in advance of the flood and the buyout serves the greater public purpose of reducing future flood damage. FEMA contracted in U.S. fiscal year 2000 to plan and design a comprehensive assessment of the NFIP. Although the scope of the assessment has not been determined, one topic being considered is the relationship between disaster assistance and flood insurance.[18]

The Task Force also questioned the length of the 30-day qualification period before flood insurance in the United States comes into effect. It believed 30 days was short enough in the Red River basin to enable residents to await predictions of the spring flood risk before making insurance purchase decisions. U.S. legislation, which applies nationwide, increased the waiting period from 5 to 30 days in 1994. The Red River basin is unusual in that the extremely flat terrain can mean long flood travel times, with floods often being identifiable well in advance. The Commission understands that, under some circumstances, a long qualification period may discourage the initial purchase of flood insurance, particularly if severe flooding usually occurs only at certain times of the year and coverage would not begin until after the highest risk had passed. On the other hand, under other circumstances a short qualification period may discourage the maintenance of flood insurance coverage, since those insured may choose to evaluate risk as floods develop and purchase insurance only immediately prior to a perceived flood threat. The Commission supports measures that will increase the purchase and retention of flood insurance in the U.S. portion of the basin. The Commission understands that FEMA is reviewing the length of the qualification period and suggests that it consider Red River basin experiences within its larger, nationwide review.

As in the United States, standard residential property insurance policies in Canada do not cover flood damage. In Canada, no other source of coverage is presently available. Moreover, since the end of Canada's federal-provincial Flood Damage Reduction Program in 1993, there is a lack of current floodplain information, and there are currently no incentives to obtain the information needed to assess the overall level of flood risk. The Commission concurs with the Task Force's suggestion that, despite the smaller potential subscription base in Canada and the concentration of the majority of Canada's 1,300 flood-prone communities in the Great Lakes–St. Lawrence River basin, the issue of flood damage insurance deserves examination as a means of placing the risk on those living in flood-prone areas, and of providing an incentive for the adoption of mitigation measures by those at risk.

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[15] FEMA, *NFIP Call for Issues Status Report* (June 2000) p. II-2-3.

[16] Greenhorne & O'Mara Inc., *Basement Performance Assessment in Minnesota and North Dakota, Report to the Federal Emergency Management Agency* (February 1998).

[17] FEMA, *NFIP Call for Issues Status Report* (June 2000) p. I-5-22.

[18] FEMA, *NFIP Call for Issues Status Report* (June 2000) p. I-10-29.

Issues were raised on both sides of the border regarding crop insurance. These issues were not reviewed by the Commission, but will need to be addressed by governments, ideally as they develop comprehensive basin-wide plans for the Red River basin.

J. Emergency Management

While emergency management operations in both countries were generally successful in dealing with the 1997 flood, the Commission heard a number of concerns about confusion during the time of the crisis. These concerns included not knowing who was in charge and the lack of clear communications with respect to flood warnings and evacuation procedures. With several levels of government in two countries and various emergency organizations involved there was, and still is, considerable apprehension over the way the situation was handled in many areas. In the United States, the President's Long-term Recovery Task Force provided a framework for federal action shortly following the flood and an action plan in December 1997.[19] In Canada, recovery operations and costs were handled through the federal Disaster Financial Assistance Arrangements (DFAA) and the Canada–Manitoba Agreement on Red River Flood Disaster Assistance (1997). At the binational level, the Canada–United States Agreement on Cooperation in Comprehensive Civil Emergency Planning and Management provides a good framework for such emergencies, but does not specifically address local Red River flooding considerations. As indicated in Conclusion 1 of this report, floods of the same magnitude as 1997 or greater can be expected to occur in the future. Emergency management procedures should be fine-tuned for the Red River basin based on the experience gained in 1997. The Commission recommends that:

> **IJC Recommendation 15:** ***Within the current context of Canada–United States cooperation for civil emergency planning and management, governments should develop more detailed bilateral emergency planning and management arrangements with specific adaptations to Red River flooding.***

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[19] *Final Report of the President's Long-term Recovery Task Force, Minnesota, North Dakota, South Dakota* (December 1997).

K. Data and Decision Support

Successful floodplain planning and management, including flood preparedness and mitigation, require reliable, accurate, compatible and accessible data. It became evident early in the Commission's study, when attempting to assemble data needed for an analysis of flood issues, that fragmented and incomplete data and information are major obstacles to better flood planning and preparedness in the Red River valley.

In the early stages of its investigations, the Task Force consulted data users in the basin to identify data needs. Some of the needs identified included better means of accessing data and disseminating it to the public, more efficient data exchange between agencies involved in floodplain management, and greater database integration within the basin. These needs were highlighted throughout the work of the Task Force, not only in relating data across the international boundary, but also within each of the jurisdictions. If appropriate decisions are to be made to reduce flood damage in the future, topographic, hydrometric, meteorologic and other flood-related data must be improved, and systems to make data more readily available and accessible to agencies and the public must be developed. The Task Force pursued several initiatives that provide the basis for better decision support in the basin. These included the development of a distributed database, improved digital elevation mapping and modeling, a Web-based information network, and the conceptual framework for a decision-support system. One of the main objectives of this work was to ensure that data, models and information collected and managed by Canadian and U.S. agencies in the basin would be more accessible for purposes of improved floodplain management and for emergency planning, response and recovery.

(1) Data and Information: Analysis of future flood control measures and of the operation of flood control structures, and the evaluation of different hydrologic scenarios, depend on accurate and detailed topographic mapping of the basin. Topographic data is particularly important in the Red River valley, where small differences in flood levels can mean large differences in the extent of the area flooded. The Task Force found that current mapping of high-risk areas was not adequate for modeling and analysis of flood risk, or for the consideration of flood protection options. Among other things, the Task Force produced high-resolution digital elevation data for the lower Pembina River and for the area south of the Winnipeg Floodway, and analyzed data collection technologies.[20] Through these efforts, the Task Force found that airborne laser mapping can be a fast, reliable, and cost-effective method of obtaining three-dimensional data suitable for the creation of a Digital Elevation Model (DEM). There is considerable interest in the development of detailed topographic data by those who recognize its usefulness in supporting floodplain management. While the costs of acquiring high-resolution digital elevation data are substantial, use of these data will yield significant future benefits. The Task Force's work

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[20] U.S. Army Corps of Engineers, Engineer Research and Development Center, "Evaluating IFSAR and LIDAR Technologies Using ArcInfo: Red River Pilot Study," (in preparation).

U.S. Army Corps of Engineers, Engineer Research and Development Center, Fort Belvoir

Fused imagery, Interferometric Synthetic Aperture Radar (IFSAR) with Light Detection and Ranging (LIDAR), shows topographic relief in the Pembina, North Dakota, area.

in this area and recent mapping by others in the Fargo, Wahpeton and Breckenridge areas provide partial DEM data and lay the groundwork for the acquisition of further high-resolution elevation data.

The Commission supports the Task Force's recommendation that governments pursue the development of a seamless DEM for the basin. This work could best be pursued through a coordinated effort that involves sharing of expertise, funds, and data. Data sets developed should be made freely available without any use or sharing constraints. The Commission recommends that:

> **IJC Recommendation 16:** ***Development of the digital elevation model for the Red River basin, with high resolution in appropriate high flood risk areas, should be pursued and completed through collaborative initiatives of federal, state, provincial and local governments.***

In addition to topographic data, some of the most basic data for flood planning and preparedness are hydrological and climatological data. Over the past two decades, fiscal restraint and budget cuts in government agencies have resulted in considerable reductions in stream gauging and meteorological networks used in flood forecasting and measurement of river flows. The Commission's 1997 interim report contained a number of recommendations for modernizing and flood-proofing hydrometric networks in the basin. According to the Task Force, significant steps have been taken in both countries to address these recommendations. In addition, improvements to the climatological networks have been made. Because of their critical importance in tracking weather systems and forecasting flood events, responsible government agencies should undertake a binational assessment of the existing hydrological and meteorological networks, including soil moisture and snow pack measurements, and ensure that an appropriate network of stations is in place for effective flood forecasting and tracking. This will require governments to make long-term commitments to maintain the networks in a state of readiness and provide data for shared use without cost and in a timely manner. In addition, the Commission recommends that:

> **IJC Recommendation 17:** ***Federal, state and provincial governments should develop and implement a binational agreement to establish an appropriate network of hydrological and meteorological stations and data exchange for floodplain management and flood forecasting in the Red River basin.***

There is a need for consistency in the reporting of river levels along the length of the river. Current practice in the United States is to report river level data and forecasts in terms of the gauge height (local datum) at each gauge site. In Canada, they are reported in elevations above mean sea level (standard datum). This inconsistency can lead to misunderstandings and confusion when assembling basin-wide information. The Task Force also noted a number of concerns with respect to the different vertical datums used as references for surveying and mapping purposes in the two countries. The Commission endorses the Task Force's recommendation regarding datum standardization and encourages governments to convene a meeting of datum experts to discuss datum issues.

(2) Modeling: Mathematical models of the Red River basin play an important role in forecasting floods, predicting the extent of flooding, and planning for future floods. Experience during the 1997 flood demonstrated that improvements to existing models were needed, especially for overland flows, so that better predictions of the extent of flooding could be made.

As pointed out by the Task Force, improvements in flood forecasting procedures have been made in both countries since the 1997 flood. In the United States, the National Oceanic and Atmospheric Administration's National Weather Service has reviewed in detail the technical procedures used to produce forecasts for the Red River. The National Weather Service has several efforts underway to improve these procedures. These include development of a dynamic flood routing hydraulic model (FLDWAV) for the Red River, modification of its models to better reflect overland flows, recalibration of the forecasting system, development of an enhanced system for utilizing snow data, and incorporation of improved soil moisture and precipitation data in Red River forecasts. In addition, the National Weather Service is implementing an Advanced Hydrologic Prediction System that takes into account the relative uncertainty in hydrologic variables. In Canada, the federal and provincial governments, supported by the Task Force, have focused on improvements to the forecast networks and further development and implementation of the one-dimensional unsteady-state hydraulic model (MIKE 11) developed by the Task Force for modeling flood flows. Because the systems are essential to flood preparedness, governments should ensure that resources are made available for their continual improvement and enhancement.

The ultimate objective of flood forecasting is to ensure that residents and emergency managers are kept informed of anticipated river levels so that appropriate action can be taken. At its public hearings and meetings over the duration of the study, the Commission heard many complaints about the inability of the public to understand forecasts. Differences in approaches to communicating forecasts to the public, both between the two countries and among agencies in each country, created confusion during the 1997 flood. While improvements to forecasting techniques will provide better forecasts, the difficulties with communicating these forecasts will likely remain unless coordinated steps are taken by governments and agencies in the two countries to address them. As pointed out by the Task Force in its interim report, effective communication of both technical and nontechnical information is a challenge, especially during disasters like the 1997 flood. In some cases, local officials and individuals did not place credence in early flood forecasts; others did not understand the significance of the forecasts; still others did not know which source was the most credible. The public needs to be made aware of the official source of reliable forecasts. The variables inherent in the forecasts must be easily understood. The Commission re-emphasizes the need to simplify and clarify communication and dissemination of forecast information to the public.

Flood forecasting and communication activities are currently undertaken by the responsible agencies at the federal, state and provincial levels. There are informal arrangements for sharing flood forecasting data and information. The Commission nevertheless supports the Task Force's recommendation calling for the establishment of a Red River Basin Flood Forecasting Liaison Committee to improve communications among forecasters and with the public. The Commission believes that its International Red River Board could undertake this mission. The Commission recommends that:

> **IJC Recommendation 18:** ***The governments should authorize the Commission to establish a binational Red River Flood Forecasting Liaison Committee under the International Red River Board to improve interjurisdictional coordination and to help ensure that clear, understandable and compatible forecasts are issued to the public.***

At the time of the 1997 flood, Red River basin models were not capable of effectively simulating floods involving complex overland flows. To better reflect breakout and overland flows, examine the downstream effects of flood peak reduction scenarios, and evaluate the spatial extent of large floods, the Task Force developed two new hydraulic model applications for the basin. The U.S. Army Corps of Engineers applied the one-dimensional Unsteady NETwork (UNET) model for the Red River from Lake Traverse to Letellier, Manitoba. Klohn-Crippen Consultants, Ltd. applied a similar one-dimensional unsteady-state flow model (MIKE 11) for the Red River from Grand Forks to Selkirk. The model applications have been developed to simulate various flood flows under varying conditions and can thus help answer a myriad of "what if" questions related to the likely effects of flood mitigation and protection works. Detailed information about the models developed can be found in the report of the Task Force's Tools Subgroup.[21]

While much work has been done to improve flood modeling capability, these efforts cannot be considered complete. The accuracy of the models can and should be improved through acquisition of more detailed topographic information, enhancement of real-time data networks, and strengthened hydrologic understanding. The Commission stresses the importance of maintaining and improving the models so that they remain useful for future floods. The modeling work undertaken by the Task Force focused on the mainstem of the Red River and an application for the lower Pembina River. The latter work is described in this report in the section on the Pembina River. Additional work is needed to further refine existing models and develop new ones to examine more frequent, smaller floods on the mainstem of the Red River and tributary floods, and to address economic, social, and ecological issues related to flooding.

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[21] Halliday, R., and Jutila, S., *Hydrologic and Hydraulic Modeling in the Red River Basin, A Report of the Tools Subgroup to the International Red River Basin Task Force* (November 2000). (Available at: www.ijc.org)

In pursuing improvements in modeling, model developers and operators should remain sensitive to compatibility issues regarding both data input and the actual models themselves. The potential for different same-purpose models to yield inconsistent results can lead to confusion and, at worst, to open disagreement over the "right" answers. To ensure compatibility of model results, the Task Force's modelers used a common database and calibrated the hydraulic models so that they produced consistent results in the border region. While using two well-coordinated models proved effective in this instance, the Commission suggests that basin-wide problems require basin-wide approaches. The Commission encourages governments to develop basin-wide models in the long term. In the meantime, the Commission endorses the Task Force's recommendation to support and improve the UNET and MIKE 11 models and further recommends that:

> **IJC Recommendation 19:** ***As a long-term priority, government agencies responsible for flood forecasting and mitigation measures should develop basin-wide models rather than separate but coordinated models for each country.***

(3) Information Management: To satisfy the identified need for better access to data and information in the Red River basin, the Task Force completed the first stage of building a searchable database by identifying information providers and the types of flood-related information they have available. The goal of the database is to make data relevant to floodplain management and flood disaster activities readily available to all interested persons. The Task Force envisioned that the database would be constructed around existing communications and computing technology. This would enable the various information sources to be linked as a "virtual" basin-wide database. Rather than gathering hard-copy information in a central clearinghouse, information would be available electronically. Each of the underlying databases would continue to be maintained and operated by the data provider. Detailed information about the virtual database concept can be found in the report of the Task Force's Database Subgroup.[22]

The integration of computer models with the virtual database would provide a powerful means to analyze flood-related problems in the basin. The concept of a binational information base for floodplain management sparked interest from the Global Disaster Information Network (GDIN), a U.S. federal government interagency program. The goal of GDIN is to foster effective sharing of disaster-related information through the use of evolving information technologies. GDIN worked in partnership with the Task Force throughout the study on the development of the virtual database, networking, mapping, and a decision-support system. Through these cooperative efforts, the Red River Basin Disaster Information Network (RRBDIN) was launched to draw together data providers and users in a single on-line source to locate and use information on floodplain management issues in the basin (www.rrbdin1.org). The Task Force and GDIN also jointly sponsored "virtual forums": on-line networking and information sessions. This work should continue beyond the end of the Task Force's mandate.

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[22] Simonovic, Sloban P. and Birkenstock, Terry, *International Red River Basin Task Force Database Subgroup Final Report: Red River Flooding* (February 2000). (Available at: www.ijc.org)

The Task Force completed the first stage of building a searchable database for the basin that identified all information providers and catalogued metadata (data about data) for the data sets. Limited funding curtailed further development planned for U.S. metadata. On the Canadian side, a number of roadblocks were encountered in the development of the integrated database. These included lack of accessibility to data, limits on accessibility imposed by security requirements of internal networks, and policies of cost recovery that make access to data expensive for agencies and other data users. These restrictions not only limited the ability of the Task Force to make progress, but, as the Task Force pointed out, could ultimately put the public at risk by limiting public and agency access to data needed to respond to a flood threat or to enable interested parties to consider appropriate mitigation measures. The Commission recommends that:

> **IJC Recommendation 20:** ***The Canadian government should review its data and information management policies to ensure that topographic, hydrometeorological, and other flood-related data collected under government programs are made available without restrictions or conditions that limit their accessibility.***

Since the Task Force issued its final report, the Commission has continued to work with government agencies to further develop the virtual database, which it considers an important element in flood management. Building on the virtual database, a decision-support system would enable the public and flood managers to evaluate the impact of various flood scenarios. The Task Force developed the conceptual model for such a decision-support system. In the United States, the U.S. Army Corps of Engineers is interested in developing a prototype decision-support system for the basin, while the U.S. Environmental Protection Agency is making funds available through the Commission's International Red River Board to create an information network linking various parties within the basin. The Red River Basin Board, the Red River Institute, and Prairie Public Broadcasting have also shown interest in this work. Ultimately, the Commission envisions collaborative efforts on both sides of the border linking people throughout the basin and leading to real-time information sharing, on-line education, and integrated databases and models in an on-line format, usable by managers and other user groups throughout the basin and accessible to a broad public. Efforts to date have exploited the most advanced collaborative technologies and laid the groundwork for achieving this vision. The Commission strongly advocates continuation of these important efforts and recommends that:

> **IJC Conclusion 6:** ***Further improvement and maintenance of the Red River virtual floodplain management database is required. Federal, state and provincial governments and local authorities must maintain a high level of involvement in further database development and in improving data accessibility.***
>
> **IJC Recommendation 21:** ***Governments should ensure that progress continues in building a binational, virtual network linking the people, data, and models for the Red River basin.***
>
> **IJC Recommendation 22:** ***Federal, state, and provincial governments should work with basin organizations to complete in a timely manner the development of a prototype decision-support system and establish a cooperative mechanism for coordination and funding its further development and implementation.***

6

Environmental Considerations

There is a risk that when fighting a flood, recovering from its ravages or planning for protection in its aftermath, attention will be focused on dealing exclusively with the direct impact the flood is having or has had on people and their possessions in the floodplain. Insufficient thought may be given to what impact the flood might be having on the natural environment of the floodplain—the river, floodplain flora and fauna and the floodplain ecosystem in general.

The floodplain has long been the site of urban and agricultural development that has severely altered the pre-settlement ecosystem and, in some cases, even threatened its very existence. Ecologically, the habitat quality of the riverine system has been reduced substantially from historic conditions through such actions as channelization, diking, and damming. Land use changes have increased sediment transport. Wetlands have been reduced, fragmented, and degraded. The numbers and types of plant and animal species have been markedly reduced, with some species threatened, endangered, or gone from the region entirely.[23] Despite historical changes, the Red River basin also contains well-recognized treasures, such as the trophy catfish fishery in the Red River mainstem. The flood of 1997 challenged the riverine ecosystem and the recovery and future protection efforts may increase that challenge unless appropriate steps are taken. Future protection efforts may provide opportunities for ecosystem enhancement.

In its interim report, the Task Force highlighted some of the key environmental issues related to the 1997 flood. These included: releases of hazardous materials, both commercial and residential; untreated discharges from sewage and related facilities; handling of dead animal carcasses; contamination of groundwater; human health concerns related to residence flooding; and the potential for a Red River–Upper Mississippi basin hydraulic connection that might result in a transfer of species between basins. In its final report, the Task Force elaborated further on the hydraulic connection at Lake Traverse and flood effects on water quality in Lake Winnipeg.

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[23] U.S. Army Corps of Engineers, St. Paul District, and Minnesota Department of Natural Resources, *Environmental Impact Study of Flood Control Impoundments in Northwestern Minnesota* (July 1996).

A. Chemical Contamination

Studies of water quality undertaken during and following the flood revealed elevated levels of bacteria, nutrients and some pesticides along the mainstem of the Red River, but no indications of significant or prolonged detrimental effects were found. Upstream from Winnipeg, fecal coliform densities exceeded only briefly the water quality objective at the international boundary, and then declined to normal levels. Other bacteria measurements showed elevated levels at several locations along the mainstem, but these were fairly consistent with flood events and may have been attributable to municipal and agricultural sources. Bacteriological contamination of groundwater aquifers in areas south of Winnipeg was found to have taken place due to floodwaters entering the aquifers through active wells and improperly sealed abandoned wells. After the flood, Manitoba reported that wells were rehabilitated by pumping, followed by chlorination. Abandoned wells were sealed and several active wells were equipped with proper sanitary seals.

Because of its importance to the economy of Manitoba, both from a recreational and commercial fishery perspective, the Task Force addressed the impact of the flood on the water and aquatic resources of southern Lake Winnipeg. While elevated levels of nutrients, trace elements (cadmium, chromium, arsenic, zinc), and some pesticides were noted, it was not possible to confirm whether these were attributable to the flood event or whether they reflected normal ranges. The only significant finding related to toxaphene apparently released during the flood. Concentrations of this pesticide have increased in fish tissue since 1997 but do not pose a health risk. As recommended by the Task Force, the Commission encourages governments to continue to monitor toxaphene in the Lake Winnipeg ecosystem until concentrations decline to pre-1997 levels. Other trace organics, such as PCBs and DDT, generally increased in fish tissue following the flood event, but their concentrations remained well below consumption guidelines for the protection of human health. Detection of these persistent toxic contaminants, whether related to the flood event or not, is a cause for concern. While voluntary programs may be in place in the various jurisdictions to collect used pesticide containers and other household and on-farm wastes, there does not appear to be a systematic program in any jurisdiction to verify the efficacy of the voluntary programs or to eliminate the potential for accidental release of banned and other hazardous chemicals through enhanced voluntary or mandatory measures. While use of some hazardous materials may be beneficial in agricultural operations when properly used, only minimal quantities should be stored in the 500-year floodplain to reduce the risk to human and environmental health during flood events. There is no cogent reason for banned materials to be stored in the floodplain.

The Commission recommends that:

> **IJC Recommendation 23:** ***Governments should take immediate steps to ensure that all banned materials such as toxaphene are removed from the Red River basin. Governments should also ensure that potentially hazardous materials are not stored in the 500-year floodplain, although reasonable quantities of such substances could be maintained in the floodplain for immediate use.***

B. Interbasin Transfer of Alien Invasive Species

Historically, there has been some movement of waters in time of flood across the continental divide in the upper part of the Red River basin. The Commission heard concerns expressed that the natural connection between the Little Minnesota River in the Mississippi River basin and the Red River in the Hudson Bay basin provided the potential for transferring alien invasive species from one basin to the other. The Task Force examined the issue and concluded that, although the potential for transfer of species between basins appears remote, the issue deserves attention because of the severe consequences it could have for the aquatic environment. The Commission supports the need for studies to examine means of eliminating hydraulic interbasin connections and the need for biological monitoring to identify invasive species that may create a risk to the aquatic environment. If this monitoring were to indicate the potential for transfer of invasive species across the divide, the Commission would encourage immediate action to prevent such transfer. The Commission endorses the Task Force recommendation that any modifications to operating plans or structures associated with Lake Traverse must include consideration of their potential to increase the possibility of interbasin transfers.

C. Protection and Enhancement of the Floodplain Environment

A great deal of effort and large sums of money were devoted to enhancing flood protection works throughout the basin immediately prior to the flood. Most of these were temporary fixes done under adverse weather conditions and in haste. Under these circumstances, little attention was paid to the environment. Flood mitigation policy in both countries must have as its objective both the reduction of damage to persons and property and protection of the environment. As previously discussed, extensive fiscal resources are being devoted to improving the flood defenses of communities and private property throughout the Red River basin. As efforts proceed, it is imperative that the defenses take into account the protection and enhancement of the environment. For example, there may be significant opportunities, perhaps in conjunction with efforts to prepare for future flood events in the Red River basin, to restore wetlands or improve fish and wildlife resources that have been so drastically affected by human activities. Numerous fish passage restoration or modification projects are already completed or underway in the Red River valley,[24] and any new projects should include such consideration. The Commission recommends that:

> **IJC Recommendation 24:** ***Flood protection projects focus not only on reduction of flood damage but also on protection and enhancement of the floodplain environment.***

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[24] Correspondence from the U.S. Department of the Interior, Fish and Wildlife Service, September 19, 2000.

7

Managing the Floodplain—Comprehensive, Integrated Planning

The Commission has been impressed with the complexity of the problem confronted by the residents of the Red River basin in dealing with the ever-present risk of flood. Working on a regional basis, as communities, or as individuals, they face a daunting challenge. In the flat terrain, what is done in one part of the basin may have severe consequences for those living in other parts of the basin. Seemingly reasonable attempts to protect a home or a village or a town can cause significant flooding both up and downstream. Efforts to improve urban and agricultural drainage and move water more quickly into streams and rivers can, under some circumstances, intensify flows that already lap at the top of downstream flood protection works. Any construction along the river may permanently destroy valuable habitat and degrade the precious riverine ecosystem.

Time and funding limitations did not allow the Commission to take a comprehensive approach to the solution of Red River basin flood problems. Support by city of Winnipeg and province of Manitoba made possible a more complete look at Winnipeg's flood problems, but even that review did not fully consider the upstream and downstream impacts of possible mitigation measures. Solving the flood damage reduction problems of the Red River basin while concurrently protecting and enhancing the floodplain environment will require full use of all the structural and non-structural methods available. No one approach—reservoir storage, levees, relocation, flood-proofing , micro-storage, wetland restoration—will solve all the problems by itself. *There are no silver bullets.* Whether the challenge is protection of an individual, a community, or the basin as a whole, all approaches to damage reduction should be considered, and, where appropriate, integrated into the solutions. The Commission believes that solutions to the problems of cities, villages and individuals must be sought through a comprehensive examination of the flood damage problems of the basin. Fortunately, technology is rapidly making such broad-scale approaches possible. As previously noted, there have been significant improvements in hydraulic modeling, weather forecasting and remote sensing that cut the time required for studies and broaden the knowledge base of those who must carry out such analyses. The analytical work undertaken by the Task Force has moved the entire basin forward on these issues, but it has only been a first step.

The Commission concludes that:

> **IJC Conclusion 7:** ***Large and small communities throughout the Red River basin will remain at undue risk until a comprehensive binational multi-faceted solution to the full range of flood problems is developed and implemented. Such a solution will require use of all flood mitigation methods, both structural and non-structural, and must take into account potential impacts on the environment.***

The Commission recommends that:

> **IJC Recommendation 25:** ***Governments immediately take steps, on a binational basis, to begin development of a comprehensive flood damage reduction plan for the Red River basin.***

8

Managing the Flood Challenge—Institutional Arrangements

A. The Complexities of an International Basin

The hydrologic system of the Red River basin is complex. It is influenced by many natural and human forces. To deal with this system, dozens of government agencies and organizations have evolved with management responsibilities or interests in various aspects of its water and land resources. These resources are managed and controlled through myriad federal, provincial, state and local laws, regulations, rules, and ordinances. In addition, there are a number of binational, interstate and international arrangements as well as committees and working groups that oversee and coordinate many aspects of basin water management. The ponderous nature of this labyrinth of agencies and mechanisms calls for better coordination and integration of activities on a basin-wide basis. Preparing for future floods is one component of this broader need.

Major floods capture attention and stimulate remedial action. In the quiet periods between floods, the commitment to action declines as the immediacy and the apparent threat from flooding recedes. Mitigation activities, including the actions recommended by the Commission and the Task Force, need to be implemented over time and adapted as circumstances change. Governments must assume responsibility for providing the leadership and the continuity to ensure that appropriate actions are taken. Because the river basin straddles the Canada–United States boundary, two countries are involved and compatibility and integration of planning and implementation across the border will be critical. *The international boundary dividing the basin must not be a hindrance to achieving sound planning and implementation of basin-wide mitigation activities.* While recognizing that development and management of comprehensive flood damage reduction efforts must remain the responsibility of the various governments, the Commission considers that there is also a need for a basin-wide, binational institutional structure and perspective to address flood management issues and assist in moving forward to deal with their binational components.

Prairie Farm Rehabilitation Administration

The 1997 flood inundates the U.S.-Canadian border near Pembina, North Dakota, and Emerson, Manitoba.

B. Binational Cooperation

The need for a basin-wide binational approach to transboundary water management issues is generally accepted within the Red River basin. Opinions differ, however, as to the most suitable method to accomplish it. Federal, state, provincial and local governments have many well-established agencies dealing with various aspects of the flood challenge within their jurisdictions. Their responsibilities are established through laws, regulations and local statutes and the agencies are clearly capable of carrying out many of the tasks that need to be done. To meet the challenge of reducing flood risk in the Red River basin, the Commission recommends that:

> **IJC Recommendation 26:** ***Governments at all levels should undertake the following measures:***
>
> ***a. Develop and implement comprehensive, multi-faceted plans for concurrently reducing flood damage and protecting and enhancing the natural environment;***
>
> ***b. Ensure ongoing institutional support and full multi-jurisdictional participation in further development and maintenance of the Task Force's legacy projects;***
>
> ***c. Implement Commission and Task Force recommendations designed to ensure basin-wide flood preparedness and community resiliency;***
>
> ***d. Promote a culture of flood preparedness and flood resiliency in the basin;***
>
> ***e. Enhance technology and monitoring systems to provide early warnings and early action in the face of impending major floods;***
>
> ***f. Ensure binational coordination of flood forecasting and communications of forecasts to the public;***
>
> ***g. Provide opportunities for multi-jurisdictional problem solving and the exchange of best practices information; and***
>
> ***h. Integrate floodplain management activities into the broader field of watershed and basin management.***

The Commission believes that there is a need for binational institutional arrangements to deal with the transboundary issues that will arise and for monitoring progress in dealing with flood-related issues. Such arrangements should seek to:

1. involve the people of the basin to the highest degree possible;
2. obtain representation from the full range of interests;
3. elicit a wide range of views in all discussions;
4. bring forward views to governments based on consensus; and
5. obtain sufficient funds to support assigned functions.

There are currently two existing and two proposed organizations that possibly could take on all or some of these binational responsibilities. The two existing organizations are:

- The Red River Basin Board; and
- The International Red River Board of the IJC.

The two proposed organizations are:

- The IFMI-proposed Red River Basin Commission, supported by a broad-membership Steering Committee; and
- A possible International Red River Watershed Board of the IJC.

The Red River Basin Board is a not-for-profit corporation chartered under the laws of Manitoba, North Dakota, Minnesota, and South Dakota. It is dedicated to innovation in the management of the Red River basin's water and represents a grassroots effort to address issues in a basin-wide context. Its board of directors has 21 members representing local government (cities, counties, and rural municipalities), watershed boards, water-resource districts, First Nations and Native Americans. The Board recently agreed to expand membership to include representatives from the federal government and environmental organizations. There are also three at-large members and members appointed by the governors of North Dakota, Minnesota and South Dakota and the premier of Manitoba.

The mission of the Red River Basin Board is to develop a comprehensive water management plan that would then be implemented by other agencies within the basin. It also seeks to serve as an information clearinghouse; to provide public information on basin issues; to serve as a forum for discussion, consensus building and dispute resolution, including inter-jurisdictional differences, in the management of surface and groundwater supplies in the Red River basin; and to provide advice to governments on all aspects of water management.

The International Red River Board of the IJC has recently been formed by the amalgamation of two of the Commission's advisory boards, the International Red River Pollution Board and the International Souris–Red Rivers Engineering Board.[25] The amalgamated board, whose fundamental mandate is to prevent and resolve water-related disputes between Canada and the United States, will continue to assist the Commission with the responsibilities assigned to it in the Red River basin by the governments of Canada and the United States under the Boundary Waters Treaty. These include maintaining continuous surveillance over the quality of the water and the health of the transboundary aquatic ecosystem, and monitoring plans, policies, and developments that may adversely affect the quality of the water and the health of the ecosystem; reporting on the use and apportionment of the waters; and developing plans of mutual advantage for the use of these waters. The amalgamation provides for an ecosystem approach in dealing with transboundary issues related to the Red River. The Board currently is composed of federal,

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[25] The functions of the International Souris–Red Rivers Engineering Board have been divided between the new International Red River Board and a newly created International Souris River Board.

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state, and provincial members, but is being expanded to provide for local members. As with other Commission boards, members serve in their personal and professional capacity and not as representatives of their governments or agencies.

The Red River Basin Commission is an organization being proposed by the International Flood Mitigation Initiative (IFMI), an ad hoc binational group launched in December 1998 by the North Dakota Consensus Council with funding from FEMA and the province of Manitoba, to address the mitigation of flood damage on the mainstem of the Red River and its tributaries. IFMI participants established a vision, mission, and goals, then worked on a basin-wide flood mitigation strategy. Initiatives being pursued include: basin-wide coordination and cooperation; public education, research and mapping; and flood resilience. IFMI has pursued funding and organizational arrangements to ensure that work on its initiatives will continue after it presents its final report, in November 2000, to the governors of North Dakota, South Dakota, and Minnesota and to the premier of Manitoba. As proposed by IFMI, the Red River Basin Commission would provide a coordinating framework for government and private sector flood mitigation actions and decisions along the Red River and ensure progress of flood-related activities in the basin. Its membership would include the premier of Manitoba, the governors of Minnesota, North Dakota, and South Dakota, and possibly federal representatives. The Red River Basin Commission would be supported by a steering committee, which would serve as a forum for participants to develop proposals and coordinate the implementation of agreements. The steering committee would include federal, state, provincial, municipal, non-profit and private sector representatives.

What is a Watershed Board?

IJC international watershed boards...would provide a much improved mechanism for avoiding and resolving transboundary disputes by building a capacity at the watershed level to anticipate and respond to the range of water-related and other environmental challenges that can be foreseen for the 21st century. This includes effective coordination of government institutions at various levels, acquisition and fostering of expertise, knowledge and information about the ecosystem of the watershed, consultation with and involvement of the full range of interests concerned, including the public, and above all the flexibility to identify and deal with unforeseen developments. This improved mechanism could be implemented without substantially affecting existing institutions.

The Commission is vitally interested in coordinating the new watershed boards with any regional (e.g. provincial-state) structures that may already exist. This will in some instances, be facilitated by inviting members of regional institutions to serve on, or be associated in some way with, the relevant IJC watershed board.

...[F]ederal, provincial, state and other forms and levels of government will all continue to play important roles in transboundary water and environmental issues. In the Great Lakes basin, the IJC's Great Lakes Water Quality boards have served as neutral forums in which federal, state and provincial decision-makers could meet to discuss issues, develop ideas, coordinate activities, reconcile differences and achieve efficiencies in water quality policies and programs that further the common interests of the region and both countries. This is a role that permanent IJC international watershed boards could be given a mandate to play in other transboundary basins.

Permanent IJC international watershed boards would provide governments at all levels, and the public at large, with independent binational institutions composed of persons expert in, and in some cases with responsibilities for, the watershed. The boards would encompass the public, private and non-governmental sectors, but would be committed to acting in the common interest.

International watershed boards...would be available for monitoring, alerting, studying, advising, facilitating and reporting on a broad range of transboundary environmental and water-related issues.

International Joint Commission, The IJC and the 21st Century *(October 1997)*.

An International Red River Watershed Board could implement the international watershed concept in the Red River basin. This concept is still under consideration by the Commission, and will be the subject of a separate report to the Canadian and U.S. governments by the Commission in due course in response to their request on watershed boards.

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An International Red River Watershed Board could implement the international watershed concept in the Red River basin. This concept is still under consideration by the Commission, and will be the subject of a separate report to the Canadian and U.S. governments by the Commission in due course in response to their request on watershed boards.

C. Additional Responsibilities for the International Red River Board

Throughout this report, the Commission has identified a number of flood-related functions and tasks that need to be pursued by governments and others. The Commission believes that its amalgamated International Red River Board, with expanded local membership, can assist in the ongoing work in the basin by assuming some of the transboundary flood-related functions that have been identified.

The Commission has developed a proposed directive for its International Red River Board, which includes the flood-related responsibilities set out in Recommendation 27. The proposed directive is attached as Appendix 5. Concurrent with the release of this report, the Commission will distribute the proposed directive in the Red River basin and will hold hearings in the basin to obtain public input on the proposal. The Commission will also discuss the proposed directive with governments to confirm its mandate and to explore funding options.

The Commission recommends that:

> **IJC Recommendation 27:** ***Governments should assign the following functions to the International Joint Commission for implementation by the International Red River Board:***
>
> ***a. Monitor progress by the governments (federal, state, provincial, municipal) in implementing the recommendations of the Commission's report on Red River basin flooding, and in maintaining and advancing the work of the Task Force's legacy projects;***
>
> ***b. Encourage governments to develop and promote a culture of flood preparedness in the Red River valley;***
>
> ***c. Encourage government efforts to develop and implement a long-term strategy for flood mitigation and emergency preparedness;***
>
> ***d. Encourage the sharing of accurate and timely transboundary information to support the development of improved flood forecasting techniques and procedures for early flood warnings and to improve communication of flood forecasts;***
>
> ***e. Provide through the activities of the Board a forum for the exchange of best practices and for other flood-related information on preparedness, mitigation, response, and recovery, to assist in transboundary problem solving;***
>
> ***f. Promote the application of innovative technologies for supporting flood modeling and mapping;***

g. ***Monitor the adequacy of data and information collection networks (meteorological, hydrometric, water quality) for flood preparedness, forecasting and mitigation, within the larger context of overall water management needs in the basin;***
h. ***Monitor potential transboundary effects of flood mitigation and other works in the basin, and encourage cooperative studies necessary to examine these effects;***
i. ***Encourage governments to integrate floodplain management activities in watershed and basin management;***
j. ***Interact with all levels of government to help decision makers become aware of transboundary flood-related and associated water management issues; and***
k. ***Assist in facilitating a consultative process for resolution of the lower Pembina River flooding issue.***

The International Red River Board will not be in a position to assume all flood-related functions in the basin. Many of these responsibilities fall within the direct authority and mandates of the federal, state, provincial and local governments and should be carried out by them. The Commission notes that there is considerable activity in the basin focused on development of effective bilateral institutional arrangements to facilitate planning, coordination and execution of flood mitigation programs. The Commission emphasizes the need for such arrangements to include federal as well as state and provincial participation. In recognition of the continuing potential for major flooding along the Red River, the Commission recommends that:

> **IJC Recommendation 28:** ***The federal governments, in cooperation with the state and provincial governments, should work with the Commission and its International Red River Board, as well as with existing and emerging bilateral organizations, to ensure that appropriate arrangements are in place to coordinate and implement measures for flood preparedness and mitigation activities and to implement recommendations of the Commission.***

The Commission looks forward to cooperating with governments and other organizations in the basin.

9

IJC Conclusions and Recommendations

Throughout this report, the Commission has referred to the work of the International Red River Basin Task Force and to its conclusions and recommendations. As noted earlier in the text, some of the recommendations have been repeated as Commission recommendations while others have simply been referred to in a general way. Appendix 2 summarizes the Commission's position with respect to each of the recommendations of the Task Force. The following lists all of the Commission's conclusions and recommendations, including those from the Task Force's final report that the Commission endorses but did not restate.

IJC Conclusions

Conclusion 1: Although the 1997 flood was a rare event, floods of the same size as the 1997 event, or greater, can be expected to occur in the future in the Red River basin. People and property remain at risk from these floods.

Conclusion 2: It would be difficult if not impossible to develop enough economically and environmentally acceptable large reservoir storage that alone would reduce substantially the flood peaks for major floods. Storage to reduce flood peaks for more frequent local floods may prove worthwhile and deserves further study.

Conclusion 3: Large-scale micro-storage has some potential to reduce flood peaks, perhaps significantly for more frequent local floods, but reliance solely on micro-storage for major flood events would be impracticable and costly. While there are many obstacles to its effective and efficient implementation, the feasibility of micro-storage for flood peak reduction should continue to be analyzed.

Conclusion 4: Wetland storage can provide an economically and environmentally beneficial method of reducing flood flows for frequent, smaller floods, but wetland storage alone is unlikely to significantly reduce the peaks of large floods on the mainstem of the Red River.

Conclusion 5: Under flow conditions similar to those experienced in 1997, the risk of a failure of Winnipeg's flood protection infrastructure is high. Public safety requires that the city, province and Canadian federal government focus immediate attention on designing and implementing measures to further protect Winnipeg.

Conclusion 6: Further improvement and maintenance of the Red River virtual floodplain management database is required. Federal, state and provincial governments and local authorities must maintain a high level of involvement in further database development and in improving data accessibility.

Conclusion 7: Large and small communities throughout the Red River basin will remain at undue risk until a comprehensive binational multi-faceted solution to the full range of flood problems is developed and implemented. Such a solution will require use of all flood mitigation methods, both structural and non-structural, and must take into account potential impacts on the environment.

IJC Recommendations

Recommendation 1: The federal governments should convene a meeting of senior federal, provincial and state officials in 2002 to undertake policy discussions and an examination of the 1997 flood, with emphasis on review of emergency plans, evacuation procedures and mitigation measures underway.

Recommendation 2: The design flood used as the standard for flood protection works for Winnipeg should be the highest that can be economically justified or, at a minimum, the flood of record, the 1826 flood.

Recommendation 3: The city, province and the Canadian federal government should cooperatively develop and finance a long-term flood protection plan for the city that fully considers all social, environmental and human effects of any proposed flood protection measures and respects both the needs of Winnipeg and the interests of those outside the city who might be affected by such a plan.

Recommendation 4: The government of the United States, in cooperation with the cities of Fargo and Moorhead and the states of North Dakota and Minnesota, should expedite the study of flood risk potential and implement plans for flood protection measures for the Fargo–Moorhead area.

Recommendation 5: The government of the United States, in cooperation with the cities of Grand Forks and East Grand Forks and the states of North Dakota and Minnesota, should ensure that the planned flood protection works are promptly and expeditiously completed.

Recommendation 6: The government of the United States, in cooperation with the cities of Wahpeton and Breckenridge and the states of North Dakota and Minnesota, should expedite approval and implementation of flood protection plans to reduce the risk of flooding at Wahpeton–Breckenridge.

Recommendation 7: The province of Manitoba and city of Selkirk should expedite studies of flood-risk potential in the Selkirk area.

Recommendation 8: To improve resiliency in the basin, governments should support enhanced research into the various social dimensions of the flood, including economic, psychological, public health and sociological impacts.

Recommendation 9: Governments at all levels should ensure that in the development of flood mitigation strategies for the basin the needs of small communities, individual isolated farmsteads and agriculture are not overlooked.

Recommendation 10: Federal government agencies, in cooperation with the state of North Dakota and the province of Manitoba, should establish a consultative group to work with local interests, including the Pembina River Basin Advisory Board, to resolve the lower Pembina River flooding issue, provide necessary resources for the group, and act to achieve a solution.

Recommendation 11: Governments should develop a binational integrated approach to mitigation initiatives at all political levels, based on a comprehensive mitigation strategy for the entire basin. In the United States, the strategy should be integrated within the overall national framework.

Recommendation 12: The Canadian federal government should establish a national flood mitigation strategy, or a broader disaster mitigation strategy, and support it with comprehensive mitigation programs.

Recommendation 13: Governments should use, at a minimum, the 100-year (1 percent) flood as the basis for floodplain regulations and revise their estimates of the 100-year flood levels based on 1997 and new data that become available.

Recommendation 14: State, provincial and other appropriate authorities should review the effectiveness of and compliance with the floodplain management regulations in the basin and take steps as needed to improve enforcement.

Recommendation 15: Within the current context of Canada–United States cooperation for civil emergency planning and management, governments should develop more detailed bilateral emergency planning and management arrangements with specific adaptations to Red River flooding.

Recommendation 16: Development of the digital elevation model for the Red River basin, with high resolution in appropriate high flood risk areas, should be pursued and completed through collaborative initiatives of federal, state, provincial and local governments.

Recommendation 17: Federal, state and provincial governments should develop and implement a binational agreement to establish an appropriate network of hydrological and meteorological stations and data exchange for floodplain management and flood forecasting in the Red River basin.

Recommendation 18: The governments should authorize the Commission to establish a binational Red River Flood Forecasting Liaison Committee under the International Red River Board to improve interjurisdictional coordination and to help ensure that clear, understandable and compatible forecasts are issued to the public.

Recommendation 19: As a long-term priority, government agencies responsible for flood forecasting and mitigation measures should develop basin-wide models rather than separate but coordinated models for each country.

Recommendation 20: The Canadian government should review its data and information management policies to ensure that topographic, hydrometeorological, and other flood-related data collected under government programs are made available without restrictions or conditions that limit their accessibility.

Recommendation 21: Governments should ensure that progress continues in building a binational, virtual network linking the people, data, and models for the Red River basin.

Recommendation 22: Federal, state, and provincial governments should work with basin organizations to complete in a timely manner the development of a prototype decision-support system and establish a cooperative mechanism for coordination and funding its further development and implementation.

Recommendation 23: Governments should take immediate steps to ensure that all banned materials such as toxaphene are removed from the Red River basin. Governments should also ensure that potentially hazardous materials are not stored in the 500-year floodplain, although reasonable quantities of such substances could be maintained in the floodplain for immediate use.

Recommendation 24: Flood protection projects focus not only on reduction of flood damage but also on protection and enhancement of the floodplain environment.

Recommendation 25: Governments immediately take steps, on a binational basis, to begin development of a comprehensive flood damage reduction plan for the Red River basin.

Recommendation 26: Governments at all levels should undertake the following measures:

a. Develop and implement comprehensive, multi-faceted plans for concurrently reducing flood damage and protecting and enhancing the natural environment;
b. Ensure ongoing institutional support and full multi-jurisdictional participation in further development and maintenance of the Task Force's legacy projects;
c. Implement Commission and Task Force recommendations designed to ensure basin-wide flood preparedness and community resiliency;
d. Promote a culture of flood preparedness and flood resiliency in the basin;
e. Enhance technology and monitoring systems to provide early warnings and early action in the face of impending major floods;
f. Ensure binational coordination of flood forecasting and communications of forecasts to the public;
g. Provide opportunities for multi-jurisdictional problem solving and the exchange of best practices information; and
h. Integrate floodplain management activities into the broader field of watershed and basin management.

Recommendation 27: Governments should assign the following functions to the International Joint Commission for implementation by the International Red River Board:

a. Monitor progress by the governments (federal, state, provincial, municipal) in implementing the recommendations of the Commission's report on Red River basin flooding, and in maintaining and advancing the work of the Task Force's legacy projects;
b. Encourage governments to develop and promote a culture of flood preparedness in the Red River valley;
c. Encourage government efforts to develop and implement a long-term strategy for flood mitigation and emergency preparedness;
d. Encourage the sharing of accurate and timely transboundary information to support the development of improved flood forecasting techniques and procedures for early flood warnings and to improve communication of flood forecasts;
e. Provide through the activities of the Board a forum for the exchange of best practices and for other flood-related information on preparedness, mitigation, response, and recovery, to assist in transboundary problem solving;
f. Promote the application of innovative technologies for supporting flood modeling and mapping;
g. Monitor the adequacy of data and information collection networks (meteorological, hydrometric, water quality) for flood preparedness, forecasting and mitigation, within the larger context of overall water management needs in the basin;
h. Monitor potential transboundary effects of flood mitigation and other works in the basin, and encourage cooperative studies necessary to examine these effects;
i. Encourage governments to integrate floodplain management activities in watershed and basin management;

j. Interact with all levels of government to help decision makers become aware of transboundary flood-related and associated water management issues; and
k. Assist in facilitating a consultative process for resolution of the lower Pembina River flooding issue.

Recommendation 28: The federal governments, in cooperation with the state and provincial governments, should work with the Commission and its International Red River Board, as well as with existing and emerging bilateral organizations, to ensure that appropriate arrangements are in place to coordinate and implement measures for flood preparedness and mitigation activities and to implement recommendations of the Commission.

Task Force Conclusions Endorsed but not Restated by the IJC[26]

Conclusion 7: There is general recognition in the region that flooding in the lower Pembina River basin has been profoundly affected by the construction of dikes and of roads that act as dikes on both sides of the boundary. Rectifying the transboundary flooding consequences of these structures will require action in both countries and there appears to be a general readiness to take such action.

Conclusion 8: Further improvement and maintenance of the [virtual] Red River floodplain management database [initiated by the Task Force] is required. Federal, state and provincial governments and local authorities must maintain a high level of involvement in further database development and in improving data accessibility.

Task Force Recommendations Endorsed but not Restated by the IJC

Recommendation 2: Future ice jam information from the entire basin should be incorporated into the [U.S. Army Corps of Engineers' Cold Regions Research Engineering Laboratory] CRREL Ice Jam Database so that ice problems in the basin can be analyzed further. Where feasible, historic ice jams from the Canadian portion of the basin should be entered.

Recommendation 3: Communities in the United States portion of the Red River basin should ensure that community-built flood damage reduction projects are certified by FEMA for 100-year or greater protection, or should participate in the Non-Federal Flood Control Works Inspection Program.

Recommendation 5: Based on results from hydraulic model studies, modify the east embankment of the [Winnipeg] Floodway to improve the performance of the Floodway entrance to lower upstream water levels and increase capacity.

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[26] Annotations in square brackets are IJC comments for clarification of context.

Recommendation 6: The west dike [upstream of the Winnipeg Floodway inlet] should be raised to allow a water level elevation of 778 feet (237 m) at the Floodway inlet structure with appropriate freeboard.

Recommendation 7: The primary diking system [for Winnipeg] should be raised where economically feasible to the elevation specified in existing legislation.

Recommendation 10: Modifications to the sewer and land drainage systems [of Winnipeg] should be optimized and undertaken once the overall plan for Winnipeg flood protection is determined.

Recommendation 11: The City of Winnipeg should give immediate high priority to the preparation of a detailed emergency preparedness and response manual.

Recommendation 12: Operating rules for new flood control measures [for Winnipeg] should be designed to accommodate all flow regimes, even those beyond design capacity. The public should be consulted on any proposed new operating rules.

Recommendation 15: The 500-year flood (0.2 percent flood) should be defined throughout the Red River basin and used to inform the public of the potential risks of flooding from rare events, including the need to buy flood insurance in the United States, and as the basis of regulations for siting and flood-proofing critical facilities.

Recommendation 16: Both North Dakota and Minnesota should consider adopting the new International Building Code that includes requirements for design and construction in flood hazard areas.

Recommendation 17: The National Building Code of Canada should specify design and construction standards for buildings in flood hazard areas such as the Red River basin. Floodplain construction requirements should be incorporated into the Manitoba code when available.

Recommendation 18: Federal, state, provincial, and local governments in the Red River basin, in conjunction with the private sector, should continue to develop, refine, and implement effective strategies to improve the disaster resiliency in basin communities. Efforts should be made to increase public awareness of flood risks throughout the basin.

Recommendation 21: The Canadian federal government should include in the Disaster Financial Assistance Arrangements provisions to allow for the permanent removal of structures in areas subject to repeated flooding.

Recommendation 25: Recovery, rebuilding, and mitigation expertise and information should be widely shared across the border in advance of flooding.

Recommendation 26: Measures of flood resilience should be developed, and a system should be established to monitor resilience in the Red River basin.

Recommendation 28: Given the transboundary nature of the [Pembina River] basin and the potential for federal involvement in funding and monitoring any agreement, federal agencies from both countries should be engaged in this process [to determine and implement solutions to flooding problems] as well.

Recommendation 29: Changes in the road network and diking system in the lower Pembina basin should be modeled by the hydrodynamic model prior to implementation of any plan to ensure that there are no unintended consequences.

Recommendation 30: The virtual database and decision-support system prototype that the Task Force has begun to develop for the Pembina basin should be continued by relevant agencies in Canada and the United States.

Recommendation 32: Any modification to existing operating plans or physical structures associated with Lake Traverse that could increase pool elevation must be accompanied by features that eliminate the southward movement of water into the Little Minnesota River.

Recommendation 34: Governments should continue to monitor toxaphene in the Lake Winnipeg ecosystem until concentrations decline to pre-1997 levels.

Recommendation 35: Hydrometric and meteorological data networks necessary for flood forecasting should be improved and maintained in a state of readiness to forecast future floods.

Recommendation 36: New geographically related data collection in the United States should be in accord with the North American Vertical Datum of 1988.

Recommendation 37: For consistency and accuracy, data used in models should take into account the differences in data at the border. Because datum conversions can affect data accuracy, any conversions between standards should be noted and reported along with the data.

Recommendation 38: U.S. National Geodetic Survey and the Geodetic Survey of Canada should convene a forum of datum experts [~~in the year 2000~~] to discuss Red River basin datum issues and develop a long-term transition plan [for resolving datum differences between the two countries].

Recommendation 39: All key data providers in Canada should make available at no cost and with no restriction the data sets necessary for the Red River floodplain management and emergency response, and regional or basin-wide modeling activities.

Recommendation 40: Data providers should remain responsible for maintaining and replicating the data sets [in the developing virtual database].

Recommendation 44: The U.S. National Weather Service should implement its Advanced Hydrologic Prediction System in the Red River basin as an early priority.

Recommendation 46: Confirm the flood peak reduction findings of Chapter 3 [of the Task Force's final report of April 2000] for large floods and examine reductions for smaller floods by implementing distributed models on tributaries such as the Mistinka, Wild Rice and Maple Rivers.

Recommendation 48: Conduct surveys of secondary roads, particularly in the central portion of the basin, with differential global positioning systems, and incorporate the results into the hydraulic models.

Recommendation 50: Measures should be taken to ensure that data supporting the operation of the hydraulic models and model outputs can be made widely available.

Signature Page

Signed on the 28th day of November 2000 as the final report of the International Joint Commission to the Governments of Canada and the United States on reducing flood impacts in the Red River basin, as requested in the June 12, 1997 reference.

L. H. Legault
Chair, Canadian Section

Thomas Baldini

Thomas L. Baldini
Chair, United States Section

Robert Gourd
Commissioner

Susan B. Bayh
Commissioner

Alice Chamberlin
Commissioner

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Appendix 1

Reference

Letters of reference to the International Joint Commission from the governments of Canada and the United States—June 12, 1997.

Minister of Foreign Affairs Ministre des Affaires étrangères

Ottawa, Canada K1A 0G2

June 12, 1997

Mr. Murray Clamen
Secretary
Canadian Section
International Joint Commission
100 Metcalfe Street
Ottawa, Ontario
K1P 5M1

Dear Mr. Clamen:

I have the honour to inform you that the Governments of Canada and the United States of America have agreed to ask the International Joint Commission, pursuant to Article IX of the Boundary Waters Treaty of 1909, and in consideration of the devastation of the flood of 1997, to examine and report on the causes and effects of damaging floods in the Red River basin, and to make recommendations on means to reduce, mitigate and prevent harm from future flooding in the Red River basin.

The Red River basin is a single drainage system which straddles both the U.S. (North Dakota, South Dakota, and Minnesota) and Canada (Manitoba). The Governments recognize that measures to address future flooding must reflect the transboundary nature of the Red River basin. A cooperative approach is desirable for dealing with issues ranging from flood forecasting, emergency preparedness and response to long-term water management and flood reduction. The Governments, therefore, request the Commission to focus on cross-border cooperation of governments, agencies and communities in the basin in its inquiries under this reference.

The Governments also recognize that the flooding in the basin is the consequence of many complex factors. Out of the experience dealing with floods in the basin, there may be important lessons for the future, which should be included in your report. It is important to identify strengths and capabilities, to be able to identify vulnerable areas in effectiveness, emergency preparedness

.../2

programs and in response planning, and other flood-related problems, and to point the way toward improvements in these measures. It is also important to recognize the costs to be avoided by prevention and planning for the future.

The Governments of Canada and the United States of America request the Commission to consider, examine and report on the following matters:

1. the history, extent, and effects of flooding in the Red River basin, with particular emphasis on the 1997 flood;

2. the relationship of the 1997 flood to past and anticipated future Red River floods;

3. the effects of flood control and other structures, changing land use and land management practices, and any other pertinent factors on flood conditions;

4. the current state of flood forecasting practices, capabilities and technologies, including the sharing of data between agencies;

5. policies, programs and mechanisms for emergency preparedness and response, and risk reduction, flood plain management and flood damage control;

6. the potential effects of weather variability on flood frequency, peak, and/or duration;

7. water quality issues associated with flood events;

8. other matters that the Commission deems relevant to the purpose of this study.

Based on these considerations the Commission should examine and make recommendations on:

1. remedial, restorative, protective or management measures that would help to mitigate the effects of flooding;

2. other innovative measures for flood reduction, damage reduction and future relief options, such as building design and construction, ring dikes, levee

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setbacks, insurance, regulation of flood plain use, watershed management, basin storage, ecological restoration and land acquisition;

3. scientific and technical investigations, applied research or demonstration projects relating to enhanced flood protection and mitigation;

4. the relevant information base, including monitoring and alerting networks, and its integration with respect to the Red River basin;

5. the objectives, parameters, organization and structure of bilateral cooperation and measures for its improvement;

6. a plan or plans of cooperative flood management, flood forecasting, emergency response and flood mitigation;

7. any other matters that the Commission deems appropriate and relevant.

The Commission is requested to estimate the benefits and costs, including non-monetary costs, should there be any, to each country of implementing any recommended or currently proposed changes, including compensatory works or measures that might offset adverse impacts to interests affected. The Commission is requested to determine the costs of any recommended changes, indicate how such costs might be apportioned between the United States and Canada, and present the bases for determining these apportionments.

In conducting its work under this reference, the Governments urge the Commission to draw upon the expertise, data, relevant studies and technology available from the provinces, states and federal governments, tribal governments, communities, organizations, academic institutions, business and others. Both Governments will endeavour to promote the participation of departmental experts in this reference study. The Governments also urge the Commission to take account of the principles of sustainable development and ecosystem management. The Governments, subject to the applicable laws and regulations, shall make available, or as necessary, seek the authorization and appropriation of funds required to provide

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promptly to the Commission the resources needed to discharge its reference obligations within the specified time period. The Commission shall develop, as soon as practicable, reference cost projections for the information of governments.

The Governments note that a variety of initiatives are underway on various matters pertaining to water or land use management, emergency preparedness and response and environmental data gathering and monitoring, and urge the Commission to draw upon these initiatives.

The Governments request the Commission to provide an interim report by December 31, 1997 describing progress of its work on evaluation of flooding in the Red River basin and identifying measures that could be implemented in the near term, and to make a full report, including recommendations of areas for further study, as soon as practicable before the end of 1998.

An identical letter is being sent to the Secretary of the United States Section of the Commission by the United States Department of State.

Sincerely,

Lloyd Axworthy

Lloyd Axworthy

United States Department of State

Washington, D.C. 20520

June 12, 1997

Ms. Kathy Prosser
Secretary, U.S. Section
International Joint Commission
1250 23d Street, N.W.
Suite 100
Washington, D.C. 20440

Dear Ms. Prosser:

I have the honor to inform you that the Governments of the United States of America and Canada have agreed to ask the International Joint Commission, pursuant to Article IX of the Boundary Waters Treaty of 1909, and in consideration of the devastation of the flood of 1997, to examine and report on the causes and effects of damaging floods in the Red River basin, and to make recommendations on means to reduce, mitigate and prevent harm from future flooding in the Red River Basin.

The Red River basin is a single drainage system which straddles both the U.S. (North Dakota, South Dakota and Minnesota) and Canada (Manitoba). The Governments recognize that measures to address future flooding must reflect the transboundary nature of the Red River basin. A cooperative approach is desirable for dealing with issues ranging from flood forecasting, emergency preparedness and response to long-term water management and flood damage reduction. The governments, therefore, request the Commission to focus on cross-border cooperation of governments, agencies and communities in the basin on its inquiries under this reference.

The Governments also recognize that the flooding in the basin is the consequence of many complex factors. Out of the experience of dealing with floods in the basin, there may be important lessons for the future, which should be included in your report. It is important to identify strengths and capabilities, to be able to identify fully vulnerable areas in effectiveness, emergency preparedness programs and in response planning, and other flood-related problems, and to point the way toward improvements in these measures. It is also important to recognize the costs to be avoided by prevention and planning for the future.

The Governments of the United States of America and Canada request the Commission to consider, examine and report on the following matters:

1. the history, extent, and effects of flooding in the Red River Basin, with particular emphasis on the 1997 flood;
2. the relationship of the 1997 flood to past and anticipated future Red River floods;
3. the effects of flood control and other structures, changing land use and land management practices, and any other pertinent factors on flood conditions;
4. the current state of flood forecasting practices, capabilities and technologies, including the sharing of data between agencies;
5. policies, programs and mechanisms for emergency preparedness and response, risk reduction, flood plain management and flood damage control;
6. the potential effects of weather variability on flood frequency, peak, and/or duration;
7. water quality issues associated with flood events;
8. any other matters that the Commission deems relevant to the purpose of this study.

Based on these considerations, the Commission should examine and make recommendations on:

1. remedial, restorative, protective, or management measures that would help to mitigate the effects of flooding;
2. other innovative measures for flood reduction, damage reduction and future relief options, such as building design and construction, ring dikes, levee setbacks, insurance, regulation of flood plain use, watershed management, basin storage, ecological restoration and land acquisition;
3. scientific and technical investigations, applied research or demonstration projects relating to enhanced flood protection and mitigation;

4. the relevant information base, including monitoring and alerting networks, and its integration with respect to the Red River basin;

5. the objectives, parameters, organization and structure of bilateral cooperation and measures for its improvement;

6. a plan or plans of cooperative (integrated) flood management, flood forecasting, emergency response and flood mitigation;

7. any other matters that the Commission deems appropriate and relevant.

The Commission is requested to estimate the benefits and costs, including non-monetary costs, should there be any, to each country of implementing any recommended or currently proposed changes, including compensatory works or measures that might offset adverse impacts to interests affected. The Commission is requested to determine the costs of any recommended changes, indicate how such costs might be apportioned between the United States and Canada, and present the bases for determining these apportionments.

In conducting its work under this reference, the Governments urge the Commission to draw upon the expertise, data, relevant studies and technology available from the provinces, states and federal governments, tribal governments, communities, organizations, academic institutions, business and others. The Governments also urge the Commission to take account of the principles of sustainable development and ecosystem management. The Governments, subject to the applicable laws and regulations, shall make available, or as necessary, seek the authorization and appropriation of funds required to provide promptly to the Commission the resources needed to discharge its reference obligations within the specific time period. Both Governments will endeavor to promote the participation of departmental experts in the reference study. The commission shall develop, as soon as practicable, reference cost projections for the information of governments.

The Governments note that a variety of initiatives are underway on various matters pertaining to water or land use management, emergency preparedness and response and environmental data gathering and monitoring, and urge the Commission to draw upon these initiatives.

The Governments request the Commission to provide an interim report by December 31, 1997, describing the progress of its work on evaluation of flooding in the Red River basin and identifying measures that could be implemented in the near term, and to make a full report, including recommendations of areas for further study, as soon as practicable before the end of 1998.

Sincerely,

Earl Anthony Wayne

E. Anthony Wayne
Deputy Assistant Secretary for
European and Canadian Affairs

Appendix 2

Conclusions and Recommendations of the International Red River Basin Task Force (TF) That Have Been Endorsed or Modified by the IJC

(TF Conclusions and Recommendations are in ordinary type)
(IJC comments or modified conclusions and recommendations are in italics)

Conclusions	**IJC Endorsed**	**IJC Modified**
Red River in History TF 1. Analysis of the geological record, historic floods of the nineteenth century, statistics, and the hydrometeorological factors that cause floods in the Red River basin indicate that floods of the same size as in 1997, or even greater, can be expected in the future. (Page TF-19) *IJC 1 - Although the 1997 flood was a rare event, floods of the same size as the 1997 event, or even greater, can be expected to occur in the future in the Red River basin. People and property remain at risk from these floods. (Page 20)*		✓
Flow Management TF 2. It would be difficult if not impossible to develop enough economically and environmentally acceptable large reservoir storage to reduce substantially the flood peaks for major floods. (Page TF-24) *IJC 2 - It would be difficult if not impossible to develop enough economically and environmentally acceptable large reservoir storage that alone would reduce substantially the flood peaks for major floods. Storage to reduce flood peaks for more frequent local floods may prove worthwhile and deserves further study. (Page 23)*		✓
TF 3. Large-scale micro-storage has some potential to reduce flood peaks on the Red River but is likely to be impracticable and costly. There are many obstacles to its effective and efficient implementation. (Page TF-28) *IJC 3 - Large-scale micro-storage has some potential to reduce flood peaks, perhaps significantly for more frequent local floods, but reliance solely on micro-storage for major flood events would be impracticable and costly. While there are many obstacles to its effective and efficient implementation, the feasibility of micro-storage for flood peak reduction should continue to be analyzed. (Page 24)*		✓

Conclusions continued	**IJC Endorsed**	**IJC Modified**
TF 4. Wetland storage may be a valued component of the prairie ecosystem but it plays an insignificant hydrologic role in reducing peaks of large floods on the main stem of the Red River. (Page TF-30) *IJC 4 - Wetland storage can provide an economically and environmentally beneficial method of reducing flood flows for frequent, smaller floods, but wetland storage alone is unlikely to significantly reduce the peaks of large floods on the main stem of the Red River. (Page 25)*		✔
TF 5. There may be many good environmental and other reasons to restore wetlands, but wetland restoration is an economically inefficient method of reducing flood damages for infrequent large floods, like the Red River flood of 1997. (Page TF-30) *IJC - See IJC Conclusion 4 above.*		✔
Winnipeg at Risk TF 6. Under flow conditions similar to those experienced in 1997, the risk of a failure of Winnipeg's flood protection infrastructure is high. (Page TF-44) *IJC 5 - Under flow conditions similar to those experienced in 1997, the risk of a failure of Winnipeg's flood protection infrastructure is high. Public safety requires that the city, province and Canadian federal government focus immediate attention on designing and implementing measures to further protect Winnipeg. (Page 29)*		✔
Lower Pembina River Flooding TF 7. There is general recognition in the region that flooding in the lower Pembina River basin has been profoundly affected by the construction of dikes and of roads that act as dikes on both sides of the boundary. Rectifying the transboundary flooding consequences of these structures will require action in both countries and there appears to be a general readiness to take such action. (Page TF-84) *IJC - The Commission endorses this conclusion but does not restate it.*	✔	
Data and Decision Support for Flood Management TF 8. Further improvement and maintenance of the Red River floodplain management database is required. Federal, state and provincial governments and local authorities must maintain a high level of involvement in further database development and in improving data accessibility. (Page TF-94) *IJC 6 - The Commission endorses this conclusion and restates it. (Page 53)*	✔	
Flood Related Institutional Arrangements TF 9. It is, of course, for the Commission and the governments to ratify an international watershed board for the Red River basin. The Task Force, however, considers that such a board, if established, might appropriately be assigned a mandate to advocate and report on flood-related issues, including the progress of governments in implementing the recommendations in this report and in maintaining and advancing the work of the Task Force's legacy projects. More particularly, this mandate could include the flood-related functions identified earlier in this section, namely:		✔

Conclusions continued	**IJC Endorsed**	**IJC Modified**
(i) Ensure ongoing institutional support and full multi-jurisdictional participation for legacy projects, the distributed data base, and computer models. (ii) Monitor implementation of recommendations designed to ensure basin-wide flood preparedness and community resiliency. (iii) Monitor and report on the implications of specific flood-related recommendations. (iv) Promote a culture of flood preparedness and flood resiliency in the basin. (v) Support of early warnings and early action in the face of impending major floods. (vi) Ensure coordination of flood forecasting information. (vii) Provide a forum for multi-jurisdictional problem solving. (viii) Provide a forum for the exchange of best-practices information. (ix) Provide knowledgeable and credible advocates to interact with the highest levels of government in order to make decision makers aware of the requirements of the people of the basin on flood-related issues and associated issues of water management. (Page TF-126) *IJC - Restated as IJC Recommendations 26 and 27. (Pages 62 and 65)*		

Recommendations	**IJC Endorsed**	**IJC Modified**
Flow Management TF 1. Wetland restoration projects for flood control should be evaluated on the basis of their local benefits and costs rather than imputing a basin-wide benefit. (Page TF-30) *IJC - See IJC Conclusion 4. The Commission concludes that wetland storage can provide an economically and environmentally beneficial method of reducing flood flows for frequent, smaller floods, but wetland storage alone is unlikely to significantly reduce peaks of large floods on the mainstem of the Red River. (Page 25)*		✔
TF 2. Future ice jam information from the entire basin should be incorporated into the CRREL Ice Jam Database so that ice problems in the basin can be analyzed further. Where feasible, historic ice jams from the Canadian portion of the basin should be entered. (Page T-34) *IJC - The Commission endorses this recommendation but does not restate it.*	✔	
Communities at Risk TF 3. Communities in the United States portion of the Red River basin should ensure that community-built flood damage reduction projects are certified by FEMA for 100-year or greater protection, or should participate in the Non-Federal Flood Control Works Inspection Program. (Page TF-37) *IJC - The Commission endorses this recommendation but does not restate it.*	✔	

Recommendations continued	**IJC Endorsed**	**IJC Modified**
Winnipeg at Risk TF 4. The design flood used as the standard for flood protection works for Winnipeg should be the highest that can be economically justified or, at a minimum, the flood of record, the 1826 flood. (Page TF-46) *IJC 2 - The Commission endorses this recommendation and restates it. (Page 29)*	✓	
TF 5. Based on results from hydraulic model studies, modify the east embankment of the Floodway to improve the performance of the Floodway entrance to lower upstream water levels and increase capacity. (Page TF-52) *IJC - The Commission endorses this recommendation but does not restate it.*	✓	
TF 6. The west dike should be raised to allow a water level elevation of 778 feet at the Floodway inlet structure with appropriate freeboard. (Page TF-53) *IJC - The Commission endorses this recommendation but does not restate it.*	✓	
TF 7. The primary diking system should be raised where economically feasible to the elevation specified in existing legislation. (Page TF-53) *IJC - The Commission endorses this recommendation but does not restate it.*	✓	
TF 8. The City of Winnipeg, the Province, and the federal government should cooperatively finance detailed feasibility studies of the two major projects that would protect Winnipeg against very large floods. (Page TF- 53) *IJC 3 - The city, province and the Canadian federal government should cooperatively develop and finance a long-term flood protection plan for the city that fully considers all social, environmental and human effects of any proposed flood protection measures and respects both the needs of Winnipeg and the interests of those outside the city who might be affected by such a plan. (Page 31)*		✓
TF 9. The three jurisdictions should work towards a Winnipeg Protection Agreement to finance the development of a long-term protection plan that would include construction of the Ste. Agathe Detention Structure or Floodway expansion. (Page TF-53) *IJC - See IJC Recommendation 3 above.*		✓
TF 10. Modifications to the sewer and land drainage systems should be optimized and undertaken once the overall plan for Winnipeg flood protection is determined. (Page TF-53) *IJC - The Commission endorses this recommendation but does not restate it.*	✓	
TF 11. The City of Winnipeg should give immediate high priority to the preparation of a detailed emergency preparedness and response manual. (Page TF-54) *IJC - The Commission endorses this recommendation but does not restate it.*	✓	

Recommendations continued	**IJC Endorsed**	**IJC Modified**
TF 12. Operating rules for new flood control measures should be designed to accommodate all flow regimes, even those beyond design capacity. The public should be consulted on any proposed new operating rules. (Page TF- 54) *IJC - The Commission endorses this recommendation but does not restate it.*	✔	
Flood Preparedness and Resiliency TF 13. In the U.S. portion of the Red River basin, the 100-year floodplain should continue to be defined in light of the best available information and the revised flood elevations should be used as the basis for floodplain regulations. (Page TF-58) *IJC 13 - Governments should use, at a minimum, the 100-year (one-percent) flood as the basis for floodplain regulations and revise their estimates of the 100-year flood levels based on 1997 and new data that become available. (Page 43)*		✔
TF 14. In Manitoba, either the flood of record or the one-percent flood should be used for Red River basin regulations. (Page TF-58) *IJC - See IJC recommendation 13 above.*		✔
TF 15. The 500-year flood (0.2 percent flood) should be defined throughout the Red River basin and used to inform the public of the potential risks of flooding from rare events, including the need to buy flood insurance in the United States, and as the basis of regulations for siting and floodproofing critical facilities. (Page TF-58) *IJC - The Commission endorses this recommendation but does not restate it.*	✔	
TF 16. Both North Dakota and Minnesota should consider adopting the new International Building Code that includes requirements for design and construction in flood hazard areas. (Page TF-59) *IJC - The Commission endorses this recommendation but does not restate it.*	✔	
TF 17. The National Building Code of Canada should specify design and construction standards for buildings in flood hazard areas such as the Red River basin. Floodplain construction requirements should be incorporated into the Manitoba code when available. (Page TF-59) *IJC - The Commission endorses this recommendation but does not restate it.*	✔	
TF 18. Federal, State, provincial and local governments in the Red River Basin, in conjunction with the private sector, should continue to develop, refine and implement effective strategies to improve the disaster resiliency in both communities. Efforts should be made to increase public awareness of flood risks throughout the basin. (Page TF-60) *IJC - The Commission endorses this recommendation but does not restate it.*	✔	
TF 19. State, provincial and other appropriate authorities should review the effectiveness of and compliance with the floodplain management regulations in the basin and take steps as needed to improve enforcement. (Page TF-61) *IJC 14 - The Commission endorses this recommendation and restates it. (Page 44)*	✔	

Recommendations continued	**IJC Endorsed**	**IJC Modified**
TF 20. While the restriction of reuse of acquired properties is prudent as applied to residential, commercial or other non-flood damage mitigation purposes, FEMA should revise its interpretation of "structures" under the Hazard Mitigation Grant Program regulations to exempt water level control devices, dikes, levees, flood walls and any other feature that would mitigate future flood losses. (Page TF-61) *IJC - The Commission notes that FEMA and the U.S. Army Corps of Engineers signed a Memorandum of Understanding regarding this issue on March 29, 2000; thus, the Commission believes there is no need for further comment. (Page 44)*		
TF 21. The Canadian federal government should include in the Disaster Financial Assistance Arrangements provisions to allow for the permanent removal of structures in areas subject to repeated flooding. (Page TF- 61) *IJC - The Commission endorses this recommendation but does not restate it.*	✓	
TF 22. FEMA and Emergency Preparedness Canada should develop an integrated approach to mitigation initiatives at all political levels based on a comprehensive mitigation strategy for the entire basin. In the United States, the strategy should be integrated within the National Mitigation Strategy. (Page TF-62) *IJC 11 - Governments should develop a binational integrated approach to mitigation initiatives at all political levels, based on a comprehensive mitigation strategy for the entire basin. In the United States, the strategy should be integrated within the overall national framework. (Page 42)*		✓
TF 23. The Canadian federal government should establish a national flood mitigation strategy, or a broader disaster mitigation strategy, and support it with comprehensive mitigation programs. (Page TF-63) *IJC 12 - The Commission endorses this recommendation and restates it. (Page 42)*	✓	
TF 24. In the U. S. portion of the Red River basin, FEMA should expand current efforts to market the sale and retention of flood insurance both within and outside the 100-year floodplain. Innovative marketing should be considered to attract and retain policy holders, including increasing the waiting period from 30 days to 60 days before flood insurance comes into effect. (Page TF-65) *IJC - The Commission supports measures that will increase the purchase and retention of flood insurance in the U.S. portion of the basin. The Commission understands that FEMA is reviewing the length of the qualification period and suggests that it consider Red River basin experiences within its larger, national review. (Page 45)*		✓
TF 25. Recovery, rebuilding, and mitigation expertise and information should be widely shared across the border in advance of flooding. (Page TF-65) *IJC - The Commission endorses this recommendation but does not restate it.*	✓	

Recommendations continued	**IJC Endorsed**	**IJC Modified**
TF 26. Measures of flood resilience should be developed, and a system should be established to monitor resilience in the Red River basin. (Page TF-66) *IJC - The Commission endorses this recommendation but does not restate it.*	✓	
Flooding in the Lower Pembina River TF 27. The International Technical Working Group, formed in 1996 but currently inactive, should be re- activated to examine the findings of the hydrodynamic model. Working with local interests, such as the Pembina River Basin Advisory Board, it should develop, implement, and fund a solution that is sustainable in the long term. (Page TF-84) *IJC 10 - Federal government agencies, in cooperation with the state of North Dakota and the province of Manitoba, should establish a consultative group to work with local interests, including the Pembina River Basin Advisory Board, to resolve the lower Pembina River flooding issue, provide the necessary resources for the group, and act to achieve a solution. (Page 41)*		✓
TF 28. Given the transboundary nature of the basin and the potential for federal involvement in funding and monitoring any agreement, federal agencies from both countries should be engaged in this process as well. (Page TF-84) *IJC - The Commission endorses this recommendation but does not restate it.*	✓	
TF 29. Changes in the road network and diking system in the Lower Pembina Basin should be modeled by the hydrodynamic model prior to implementation of any plan to ensure that there are no unintended consequences. (Page TF-84) *IJC - The Commission endorses this recommendation but does not restate it.*	✓	
TF 30. The virtual database and decision support system prototype that the Task Force has begun to develop for the Pembina Basin should be continued by relevant agencies in Canada and the United States. (Page TF-84) *IJC - The Commission endorses this recommendation but does not restate it.*	✓	
Hydraulic Connections at Lake Traverse TF 31. Engineering studies should be immediately undertaken to examine all means of eliminating the potential for the hydraulic inter-basin connection in the vicinity of Browns Valley. Governments should then implement the most feasible option. During the interim, the Little Minnesota River system should be closely monitored for undesirable species. If such species appear, immediate action should be taken to prevent their transfer to the Red River basin. Since benefits accrue basin-wide from coordinated actions taken to prevent the movement of non-native species between adjacent basins, local governments should not be held responsible for costs associated with monitoring or implementing corrective measures. While the U.S. Army Corps of Engineers will need to take the lead role in implementing this recommendation, cost-sharing options should be negotiated with Canada because of the basin-wide benefits. (Page TF-88)		✓

Recommendations continued	**IJC Endorsed**	**IJC Modified**
IJC - The Commission supports the need for studies to examine means of eliminating hydraulic inter-basin connections and the need for biological monitoring to identify invasive species that may create a risk to the aquatic environment. If such monitoring were to indicate the potential for transfer of species across the divide, the Commission would encourage immediate action to prevent such transfer. (Page 57)		
TF 32. Any modification to existing operating plans or physical structures associated with Lake Traverse that could increase pool elevation must be accompanied by features that eliminate the southward movement of water into the Little Minnesota River. (Page TF-88) *IJC - The Commission endorses the recommendation that any modifications to operating plans or structures associated with Lake Traverse must include consideration of their potential to increase the possibility of interbasin transfers. (Page 57)*	✓	
Lake Winnipeg Water Quality TF 33. Governments should take immediate steps to ensure that all banned materials such as toxaphene are removed from storage areas in the Red River basin and that potentially hazardous materials are not stored in the 500-year floodplain. Reasonable quantities of such substances could be maintained in the floodplain for immediate use. (Page TF-91) *IJC 23 - Governments should take immediate steps to ensure that all banned materials such as toxaphene are removed from the Red River basin. Governments should also ensure that potentially hazardous materials are not stored in the 500-year floodplain, although reasonable quantities of such substances could be maintained in the floodplain for immediate use. (Page 57)*		✓
TF 34. Governments should continue to monitor toxaphene in the Lake Winnipeg ecosystem until concentrations decline to pre-1997 levels. (Page TF-91) *IJC - The Commission endorses this recommendation but does not restate it.*	✓	
Data and Decision Support for Flood Management TF 35. Hydrometric and meteorological data networks necessary for flood forecasting should be improved and maintained in a state of readiness to forecast future floods. (Page TF-95) *IJC - The Commission endorses this recommendation but does not restate it.*	✓	
TF 36. New geographically related data collection in the United States should be in accord with the North American Vertical Datum of 1988. (Page TF-95) *IJC - The Commission endorses this recommendation but does not restate it.*	✓	
TF 37. For consistency and accuracy data used in models should take into account the differences in data at the border. Because datum conversions can affect data accuracy, any conversions between standards should be noted and rep[orted along with the data. (Page TF-96) *IJC - The Commission endorses this recommendation but does not restate it.*	✓	

Recommendations continued	**IJC Endorsed**	**IJC Modified**
TF 38. U.S. National Geodetic Survey and the Geodetic Survey of Canada should convene a forum of datum experts in the year 2000 to discuss Red River Basin datum issues and develop a long-term transition plan. (Page TF-96) *IJC - The Commission endorses this recommendation but does not restate it.*	✓	
TF 39. All key data providers in Canada should make available at no cost and with no restriction the data sets necessary for the Red River floodplain management and emergency response, and regional or basin-wide modeling activities. (Page TF-97) *IJC - The Commission endorses this recommendation but does not restate it.*	✓	
TF 40. Data providers should remain responsible for maintaining and replicating the data sets. (Page TF-97) *IJC - The Commission endorses this recommendation but does not restate it.*	✓	
TF 41. Development of the digital elevation model for the Red River Basin should be completed by collaborative initiatives of the relevant agencies. (Page TF-101) *IJC 16 - Development of the digital elevation model for the Red River basin, with high resolution in appropriate high flood risk areas, should be pursued and completed through collaborative initiatives of federal, state, provincial and local governments. (Page 48)*		✓
TF 42. Relevant federal, provincial, state agencies and transboundary agencies should meet to determine the interest in continuing the work of RRBDIN and if there is agreement to continue it, draw up a funding and action plan to ensure its continuation. (Page TF-103) *IJC 21 - Governments should ensure that progress continues in building a binational, virtual network linking the people, data, and models for the Red River basin. (Page 53)* *IJC 22 - Federal, state, and provincial governments should work with basin organizations to complete in a timely manner the development of a prototype decision-support system and establish a cooperative mechanism for coordination and funding its further development and implementation. (Page 53)*		✓
TF 43. A decision on whether to continue operation of the Virtual Forum should be included in the discussions on the continuation of the RRBDIN. (Page TF-104) *IJC - The Task Force and GDIN also jointly sponsored "virtual forums": online networking and information sessions. This work should continue beyond the end of the Task Force's mandate. (Page 52)*		✓
Hydrologic and Hydraulic Modeling TF 44. The U.S. National Weather Service should implement its Advanced Hydrologic Prediction System in the Red River basin as an early priority. (Page TF-107) *IJC - The Commission endorses this recommendation but does not restate it.*	✓	

Recommendations continued	**IJC Endorsed**	**IJC Modified**
TF 45. A binational Red River Flood Forecasting Liaison Committee should be established by government to improve communications among forecasters and with the public. (Page TF-108) *IJC 18 - The governments should authorize the Commission to establish a binational Red River Flood Forecasting Liaison Committee under the International Red River Board to improve interjurisdictional coordination and to help ensure that clear, understandable and compatible forecasts are issued to the public. (Page 50)*		✓
TF 46. Confirm the flood peak reduction findings of Chapter 3 for large floods and examine reductions for smaller floods by implementing distributed models on tributaries such as the Mistinka, Wild Rice and Maple Rivers. (Page TF-110) *IJC - The Commission endorses this recommendation but does not restate it.*	✓	
TF 47. As a long-term priority for government and academic research, implement a basin-wide coupled atmospheric–hydrologic model in the Red River basin. (Page TF-110) *IJC 19 - As a long-term priority, government agencies responsible for flood forecasting and mitigation measures should develop basin-wide models rather than separate but coordinated models for each country. (Page 51)*		✓
TF 48. Conduct surveys of secondary roads, particularly in the central portion of the basin, with differential global positioning systems, and incorporate the results into the hydraulic models. (Page TF-115) *IJC - The Commission endorses this recommendation but does not restate it.*	✓	
TF 49. The U.S. Army Corps of Engineers and Manitoba Conservation, operators of the UNET and MIKE 11 models respectively, should maintain the existing models and continue to seek improvements through collaboration with other agencies. (Page TF-116) *IJC - The Commission endorses this recommendation in the short-term, but makes IJC Recommendation 19 as a long-term priority. (Page 51)*		✓
TF 50. Measures should be taken to ensure that data supporting the operation of the hydraulic models and model outputs can be made widely available. (Page TF-116) *IJC - The Commission endorses this recommendation but does not restate it; see also IJC Recommendation 20. (Page 52)*	✓	
Flood-Related Institutional Arrangement TF 51. If the International Joint Commission pursues the watershed board concept, the Commission should consider establishing its initial board in the Red River Basin and assigning to this board the flood-related responsibilities outlined above. (Page TF-127) *IJC - See IJC Recommendations 27 and 28. (Pages 65 and 66)*		✓

Appendix 3

The International Joint Commission's Interim Report to Governments—December 1997

International Joint Commission
Commission mixte internationale

December 31, 1997

The Honorable Madeleine Albright
Secretary of State
Department of State
2201 C Street, NW
Washington, D.C. 20520

The Honourable Lloyd Axworthy, P.C., M.P.
Minister of Foreign Affairs
Lester B. Pearson Building
125 Sussex Drive
Ottawa, ON K1A 0G2

Dear Secretary Albright and Minister Axworthy:

The International Joint Commission is pleased to provide its interim report to the Governments of Canada and the United States under the reference of June 12, 1997 on flooding in the Red River basin. The report describes progress made by the Commission in addressing the causes and effects of damaging floods in the basin and proposes short-term actions which, if implemented, will contribute to reducing and preventing harm from future flooding. The governments asked for the Commission to provide an interim report by December 31, 1997, and a final report as soon as practicable before the end of 1998.

Progress to Date

In anticipation of receiving the June 12, 1997 request from the governments, the Commission considered generally what it might do should it receive the reference. It decided that it was essential to:

a) hold public meetings in the basin and let it be known that it would do so,
b) study the social as well as other effects of the flood, and
c) immediately visit the flooded region.

The Commission visited the flooded region in May 1997, while the downstream portion of the basin was still inundated by flood waters. Commissioners viewed flooded areas, received briefings, met with community leaders, and saw the effects of the flood first-hand. The Commission also consulted with members of its established boards in the region, obtained briefings and information on preparations and responses to the flood, and explored possible means of alleviating future damages from floods.

After receiving the June 12, 1997 reference, the Commission appointed an International Red River Basin Task Force (membership attached) to assist it in addressing the specific questions and issues posed by the governments. The Task Force is binational and multi-disciplinary. The members serve the Commission in their personal and professional capacity, in the interests of the Red River basin as a whole, and not as representatives of their agencies, organizations or other affiliations. The Commission directed the Task Force to take note of the work of other agencies and organizations in both countries, to access the full breadth of available programs and information, and to reach its decisions by consensus. The Commission also stressed to the Task Force the importance of public outreach and consultation in conducting its work.

The Commission and the Task Force held three meetings in the Red River basin with community leaders during the week of September 29, 1997. The purpose of these meetings was to obtain some initial perspectives on local impacts of the flooding and to help frame the broader issues in a way that ensures further consultations are productive. Meetings were held in Moorhead, Minnesota; Grand Forks, North Dakota; and Morris, Manitoba. The Commission also met with Manitoba Premier Filmon, Provincial Ministers Pitura and McCrae, North Dakota Governor Schafer, North Dakota Senator Conrad, and the Red River Basin Board.

The Commission participated in a number of workshops and conferences on the flood of 1997. Several of these provided valuable insights into the flood and its impacts, allowed discussion with those affected by the flood and those involved in fighting its fury, and established valuable contacts for pursuing various aspects of the reference. The Commission made presentations at two conferences: the Flood of the Century International Research Workshop in Winnipeg, Manitoba; and the North Dakota Science Council Annual Meeting and Symposium on the Red River Valley Flood of 1997 in Grand Forks, North Dakota.

The Task Force commissioned interviews with families affected by the flood and with civic officials and local emergency management coordinators. It also convened a workshop on the social dimensions of the flood. Reports documenting this work are available upon request.

In addition to issuing a directive outlining the Task Force's responsibilities, the Commission provided guidance to Task Force deliberations, participated in certain Task Force meetings and workshops, held numerous conference calls with the Task Force Co-Directors, discussed issues with Task Force members, and provided suggestions and views on Task Force work.

Task Force Interim Report

The Commission encloses for the governments' consideration the interim report of the International Red River Basin Task Force, Red River Flooding: Short Term Measures and Plan of Study, dated December 1997. The report provides a brief description of the Red River basin and its flood history, examines the 1997 flood, and offers 40 recommendations for near-term implementation to assist in preventing or minimizing damages from future floods. It addresses emergency preparedness, response, recovery, and mitigation (reducing potential future flood damages.) The report also contains a draft Plan of Study outlining the means of examining in more detail a number of issues and opportunities that could lead to long-term improvements in floodplain management in the Red River basin.

The Commission was pleased to discover the many prudent steps taken to prepare for the 1997 flood, the prevailing spirit of binational and other cooperation throughout the basin, and the measures currently being taken to better prepare for future floods. The Commission believes that the interim report will help officials in both countries identify further opportunities for improvement in flood preparedness, response, recovery, and mitigation.

The Commission has carefully considered and fully endorses the recommendations of the Task Force. Accordingly, the Commission recommends as follows:

1. Alert the public in the Red River basin to the reality that while the 1997 flood had a return interval ranging from 100 to 500 years, depending on the location, there is a statistical probability of a similar flood each year. Flood preparedness must be part of the culture of the Red River valley. Put simply, the flood of 1997 or an even larger one could happen any year.

2. A meeting of senior federal-provincial and federal-state officials in each country should be convened to undertake policy level discussions and an examination of the 1997 flood. Special attention would be placed on extending the positive aspects of flood preparation and management during 1997 to future events throughout the Red River valley.

3. Increased liaison on a regular basis among the emergency management organizations throughout the basin should be a priority in order to establish better appreciation for the manner in which each operates during an emergency.

4. During a flood, Canadian liaison officers should be present in U.S. flood emergency centers to immediately relay information to Manitoba.

5. Update and enhance existing forecast models based on 1997 data and experience, focusing specifically on improvements that can be incorporated in basin-wide forecasts prior to the 1998 season. In particular, rating curve extensions should be undertaken as soon as possible.

6. Monitor the potential effects of El Niño on 1998 weather.

7. All flood forecasting agencies should ensure that they have sufficient, experienced flood forecasting staff at all times.

8. Simplify and clarify communication between flood forecasters and those with local flood emergency responsibility throughout the basin. The dissemination of forecast information to the public through the media should be simple and the variables inherent in those forecasts easily understood.

9. The Province of Manitoba, and affected municipalities, should review all Designated Flood Area legislation and zoning provisions with the intent of widening the options for enforcement. A comprehensive program of early inspection and enforcement should be developed and implemented immediately. Once this program is implemented, non-compliant new structures should not be eligible for disaster assistance.

10. In the United States, more stringent adherence to existing policies is a necessary, immediate and effective first step for better floodplain management. Emphasis should be placed on increasing participation in the flood insurance program.

11. Update profiles, maps and flood frequency curves for the Red River basin.

12. Plans to implement new flood mitigation and flood proofing measures for individuals and communities -- if sound in economic, environmental, engineering and social terms -- should continue as rapidly as possible. All such measures, whether by government or individuals, should be coordinated and examined to determine possible damage to others within the basin.

13. Pursue an agreement between the United States and Canada to enable comprehensive civil emergency planning and management that takes into account current trade agreements between the two countries, and in particular, allows for the cross-border transfer of supplies, equipment, contracting services and labor in the event of an emergency. The agreement should look into the possibility of developing regionally specific arrangements, including state-provincial protocols.

14. North Dakota and Minnesota should review emergency measure agreements in the light of the experience of the 1997 flood.

15. A basin-wide flood forecasting committee patterned on the Souris River Flood Forecasting Liaison Committee should be established for the Red River basin.

16. In the United States where regional operations of federal agencies are divided by the Red River, a lead region should be appointed for emergency operations when a flood is forecast.

17. All flood emergency plans within the basin should be reviewed in the light of the lessons learned during the 1997 flood to prepare more effectively for the next event.

18. Each jurisdiction with responsibilities for evacuation within the basin should establish an evacuation protocol within its emergency operation plan. Particular attention should be given to the clarity and public dissemination of the protocols to help prevent confusion at the time of evacuation. Evacuation plans affect different parts of the population in different ways, and plans should take into consideration the specific requirements of vulnerable groups, such as nursing home residents.

19. Establish sufficient information centers prior to and during a flood event, through 1-800 hot lines or other well publicized toll-free telephone numbers, to provide critical information to residents of the flooded area before, during and after the event. Enhance the opportunities for Internet access, particularly for small communities and rural areas.

20. Trauma teams, emergency-response teams and personal decision-management teams should be maintained until the current demand for services subsides.

21. In future times of crisis, such support teams should be established early and begin work as soon as possible.

22. Information about flooding and the measures in place in case of flooding in the Red River valley should be introduced into the school curriculum throughout the basin, and in particular, in the communities most at risk.

23. Earlier notice should be given to Canadian Forces of their potential involvement in flood fighting in order to allow them additional preparation time.

24. Canadian military and civil authorities should reach a common understanding of the types of assistance available, particularly in terms of aid to local law-enforcement authorities.

25. Develop hydraulic models for the Red River and its major tributaries, capable of being expanded for use in forecasting and analyzing overland flooding, as well as for floodplain management.

26. Document the 1997 overland flow areas within the basin, high-water marks and head losses, wind effects, timing and extent of road or dike breaches and blow-outs, and data networks used during the flood. In addition, document the shape, elevation and alignment of roads, dikes, levees, and drains including the size of bridge and roadway openings.

27. Develop a consolidated database containing hydrometric, climatic, topographical and other technical data within the basin needed to improve forecasting and modeling capability.

28. A high priority should be given to raising existing gages above the 1997 high-water level or replacing them.

29. Add to the current gaging system in the basin and, where needed, automate reporting to increase information for flood forecasters.

30. Depending on the flood outlook, the frequency of airborne gamma snow survey flights over the Manitoba portion of the Red River valley should be increased. Increasing the density of the network by adding more flight paths should also be considered.

31. In view of the critical need for accurate flood forecasting in the Red River valley, Environment Canada should identify Winnipeg as the highest priority location for the new radar installation.

32. Innovative methods of reducing ice jams should be reviewed and expert advice sought on how ice jams may be diminished. This subject should be explored at a workshop on ice control held in the winter of 1998 and attended by international experts and basin officials. The adverse and beneficial effects of ice management on flooding and the environment need to be carefully considered.

33. Information available to individuals, government and non-government organizations and others who contributed to the flood fighting effort in 1997 should be gathered and made available at a central basin-wide archive or archives in each country.

34. Liaison among governments and industry associations throughout the basin should be encouraged and strengthened. Communications should be extended to other businesses, individual home-owners and farmers.

35. The development of a broad public awareness program within the Red River floodplain area should be started to encourage home-owners and farm operators to collect and properly dispose of all waste products that present a contamination hazard. There should also be an immediate and concerted effort to remove or secure hazardous materials stored in the floodplain.

36. An inventory of all major potential sources of contamination should be developed and maintained, to include location, elevation and type of material, and amount. This inventory should extend to the agriculture industry and include intensive livestock operations.

37. A review of legislation on the management of hazardous materials should be conducted throughout the basin.

38. Conduct an inventory of all abandoned and active groundwater wells throughout the basin and institute an aggressive program of properly sealing abandoned wells and flood-proofing active wells against floodwater contamination from the surface.

39. The natural and beneficial functions of the floodplain must be considered in the design of new levees.

40. Reasonable measures should be implemented, consistent with current operating plans, to prevent (if possible) the movement of water between the Red River and Mississippi River basins at Lake Traverse-Big Stone Lake.

The Commission commends the Task Force for providing extremely valuable guidance in such a short period of time, particularly given funding difficulties. The Commission stresses the interim nature of the report and the need to further pursue many matters raised in the reference from the governments. Under ideal circumstances, the Commission would have preferred to obtain public comment on its interim recommendations prior to presenting them to governments; however, the short time frame for preparing the interim report did not permit this approach. The Commission encourages governments at the federal, state, provincial, and municipal levels to work together to implement the recommendations, in the near-term, to provide a measure of protection and preparedness, and to minimize damages from potential flooding in 1998. Recognizing that aspects of some recommendations are already being addressed at various levels of government in both countries, the Commission emphasizes the need for governments at all levels to begin immediately to address all of the recommendations.

Further Steps

Plan of Study

In its interim report, the Task Force presents a proposed Plan of Study, which describes how it intends to complete its work under the reference. It describes the plan as a work in progress which requires further consultation and input prior to being finalized. The Commission plans to hold public consultations in the Red River basin in February 1998 to obtain public comment on the interim report and the proposed Plan of Study, and to hear from the people of the basin. Following these consultations, the Plan of Study will be finalized and work will proceed to further address the matters identified in the reference. Some work will be undertaken prior to finalizing the Plan of Study to avoid undue delays. However, this work can be adjusted, if necessary, in the light of views expressed at the public consultations.

Reporting Deadline

The Task Force recommended to the Commission that the final reporting deadline identified in the original reference be extended by six months in order to allow for the research and investigations required to address appropriately the governments' request. The Commission supports this recommendation as the Task Force has been unable to commence substantive work with respect to hydrologic and hydraulic modelling, data analysis, and social impact reviews. The Commission requests the governments' concurrence for an extension of the final reporting deadline under the reference to June 30, 1999. The Commission recognizes that this time extension results in the reference work extending over an additional spring flood season. However, implementation of the near-term measures recommended will serve to ensure better preparedness for both the 1998 and 1999 flood seasons. Furthermore, should additional near-term measures that might further alleviate potential flood damages be identified during the Task Force and Commission deliberations, these will be brought to the governments' attention for immediate consideration.

Final Report

The Commission expects that its final report will provide guidance, tools, and a framework for action that will enable jurisdictions in the basin to be better prepared for future flooding in the Red River basin. Such floods will inevitably occur again. The only questions are when, and how best to be prepared. Prior to presenting its final report to the governments, the Commission will hold public hearings in the basin to ensure that interested groups and individuals have an opportunity to present their perspectives on the matter under investigation.

The Commission would be pleased to discuss the interim report with the governments at their convenience, should they so desire.

Signed this 31st Day of December 1997 as the International Joint Commission's Interim Report to the Governments of the United States and Canada under the June 12, 1997 Reference on Red River Flooding.

Leonard H. Legault
Canadian Chairman

Thomas Baldini
Thomas L. Baldini
United States Chairman

Pierre Béland
Commissioner

Susan B. Bayh
Commissioner

Francis Murphy
Commissioner

Alice Chamberlin
Commissioner

Appendix 4

Main Text of the Final Report of the International Red River Basin Task Force—April 2000

Preface

After the devastating floods of 1997 in the Red River basin, the governments of Canada and the United States asked the International Joint Commission (IJC) to investigate the causes and effects of the flooding and to recommend ways to reduce the impact of major floods. Specifically the Commission was asked to report on the:

1. history, extent, and effects of flooding in the Red River basin, with particular emphasis on the 1997 flood;
2. relationship of the 1997 flood to past and future Red River floods;
3. effects on flood conditions of flood control and other structures, changing land use and land management practices, and any other pertinent factors;
4. current state of flood forecasting practices, capabilities, and technologies, including data sharing among agencies;
5. policies, programs and mechanisms for emergency preparedness and response, risk reduction, floodplain management, and flood damage control;
6. potential effects of weather variability on flood frequency, peak and duration;
7. water quality issues associated with floods; and
8. other matters that the IJC deemed relevant to the purpose of this study.

In September 1997, the Commission established the International Red River Basin Task Force to carry out investigations and provide advice to the Commission on the above matters. In keeping with IJC tradition, members of the International Red River Basin Task Force were appointed to serve in their personal and professional capacities, rather than as representatives of their countries, agencies, or organizations.

In December 1997, the Commission presented an interim report on flooding to the governments, in which it endorsed the report prepared by the Task Force, ***Red River Flooding: Short-Term Measures***. The report made 40 recommendations on how to improve preparedness (see Appendix 5). The recommendations were directed to governments at various levels in both countries, stressing that a significant risk of flooding will always remain and that action was required to:

- improve, clarify and coordinate various flood policies;
- simplify and clarify flood forecast information released to the public;
- enforce and adhere to floodplain management policies;

- improve emergency management coordination and plans;
- ensure support for affected families and individuals;
- make major technical improvements in forecasting and water flow models, gaging networks and surveys, and ice management, and
- address environmental concerns such as hazardous products, groundwater contamination, and considerations in levee/dike design.

The governments in the basin have substantially implemented all the recommendations. See Appendix 5 for a list of the recommendation and summary discussion of the responses to them. A more detailed review of the government responses can be found on the IJC/Task Force Web site: http://www.ijc.org/boards/rrbtf.html

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This final Task Force report follows through on the work plan outlined in the December 1997 interim report. The focus is on preparedness and mitigation for floods as large as 1997 or larger. Not all the work envisioned in the work plan could be finished because the United States government was unable to provide its full share of the funding needed for completion of the Task Force's work. Nevertheless, the Task Force has completed major technical studies that provide a firm foundation for advancing flood management in the basin. The Task Force believes that its recommendation can make a substantial contribution to helping prepare the governments and residents for the next major flood.

The Task Force established three subgroups to assist with its studies: the Database, Tools and Strategies subgroups. The members who contributed to the work of the Task Force were: **Database**: Slobodan Simonovic[1] (co-leader), University of Manitoba; Terry Birkenstock (co-leader), U.S. Army Corps of Engineers; Rick Bowering, Manitoba Conservation (Water Resources); Alf Warkentin, Manitoba Conservation (Water Resources); Glenn Radde, Minnesota Natural Resources; Randy Gjestvang, ND State Water Commission; Russ Harkness, U.S. Geological Survey; Ron Wencl, U.S. Geological Survey; Mike Anderson U.S. National Weather Service. **Tools**: Robert Halliday[1] (co-leader), R. Halliday & Associates; Scott Jutila (co-leader), U.S. Army Corps of Engineers; Rick Bowering, Manitoba Conservation (Water Resources); Alf Warkentin, Manitoba Conservation (Water Resources); Jim Solstad, Minnesota Natural Resources; Tim Fay, ND State Water Commission. **Strategies**: Bruce Rawson[1] (co-leader), Rawson Group Initiatives; Lou Kowalski (co-leader), Contractor w/U.S. Army Corps of Engineers; Larry Whitney[1], Manitoba Conservation (Water Resources); Dwight Williamson[1], Manitoba Conservation (Water Quality); Mel Sinn, Minnesota Natural Resources; Dale Frink, ND State Water Commission. The Task Force would also like to acknowledge the contribution of Paul Bourget, representing the Global Disaster Information Network. As well, the Task Force recognizes that its work could not have proceeded without the contributions of many members of the public who provided information and ideas to the Task Force, public servants at all levels of government, and the many contractors to the Task Force.

Note: The report uses U.S. spelling throughout, except for proper names in Canada. Dollars are stated in the currency of the country under discussion, unless otherwise noted. In the United States, the river is called the Red River of the North; in Canada, the Red River. This report uses the short name. In Canada the term "dike" is commonly used for riverside flood control works; in the United States, the term is "levee". In this report, the terms are used interchangeably.

U.S. and metric measurement equivalents are used except where in common practice within the basin one or the other measure is used. For example, acre foot is used throughout and no metric equivalent is provided (1 acre foot of water equals 1 233 cubic metres).

- improve emergency management coordination and plans;
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- make major technical improvements in forecasting and water flow models, gaging networks and surveys, and ice management; and
- address environmental concerns such as hazardous products, groundwater contamination, and considerations in levee/dike design.

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1

Introduction

Flooding is a fact of life along the Red River. The disastrous flood of 1997, while a rare event, was neither unprecedented nor unforeseen. As the 1997 International Red River Basin Task Force report, ***Red River Flooding: Short-Term Measures***,[2] concluded and the International Joint Commission endorsed, "The flood of 1997 or an even larger one could happen any year." In this report, the Task Force explores the implications associated with large floods—that is, floods of the magnitude of 1997 or larger—for the people, communities, and governments in the Red River basin. It considers what can be done to manage flood risks and prepare for major floods.

The International Joint Commission (IJC) and the Task Force have held public hearings and talked with residents and experts concerned about Red River flooding. Many people have offered ideas on better ways of responding to future floods and on preventing flooding and lessening its consequences. This report focuses on getting ready for the next major flood and responds to the concerns of the public and experts about the preparation needed to avoid or reduce future flood damage in a flood as large as or larger than the 1997 flood. The report also discusses issues of special concern arising from the 1997 flood.

This report focuses on getting ready for the next major flood.

In investigating what can be done about flooding in the Red River basin, this report examines the issue of storage—through reservoirs, wetlands, small impoundments or micro-storage, and drainage management. Residents often raised storage and drainage issues in discussions with the Commission and Task Force. Feelings are strong within the basin that major floods can be prevented through use of upstream storage. The Task Force considered how much storage would be required to reduce the impact of a major flood on the scale of 1997 and whether there was sufficient potential in the basin to meet that storage requirement. Some of the public concern and proposed solutions are for floods on tributaries or floods smaller than in 1997.

The Task Force considered the many ideas to mitigate the harmful consequences of smaller floods only to the extent that they may prove effective in reducing the flood peaks of major floods on the Red River. The Task Force focus precludes examination of many possibly worthwhile projects that may have tributary flood control, environmental, or other benefits.

The Task Force looked at the levels of storage needed to make a noticeable difference in flood peak levels at Grand Forks and other communities, and to reduce the risk to Winnipeg. It also examined the hydrologic regime within the basin to see whether modern land-use practices, such as wetland and other drainage, can contribute to major flooding. In addition alternative water storage and management strategies were explored, including the use of reservoirs, on-land storage, and wetlands.

The Task Force concluded that not enough economically feasible storage potential exists in the Red River basin to reduce major floods substantially. The effect on smaller floods was not investigated. Some storage projects may reduce local tributary flooding and have an effect on smaller floods in the Red River itself. Storage initiatives, such as wetland restoration, may have other non-flood-related benefits worth considering.

If, as the Task Force concludes, storage options offer no practical way to substantially reduce the risk from major floods on the Red River, then a mix of structural and non-structural options must be examined. The cities of Grand Forks and East Grand Forks are in the process of building dikes and undertaking urban renewal projects in response to the flooding suffered by those cities. Other communities are also taking action, and this report examines some of those undertakings. Winnipeg, the largest urban area within the basin, remains at risk. The city survived the 1997 flood relatively unscathed, but Winnipeg cannot afford complacency. If it had not been favored with fair weather during late April 1997, it could have suffered the fate of its southern neighbors. This report finds Winnipeg's flood defenses vulnerable and recommends actions to remedy the weaknesses.

Structural protection measures are only part of the response to living with major floods. The Task Force looked at a wide range of floodplain management issues to see how governments and residents might establish regulatory and other initiatives to mitigate the effects of major floods and to make the communities more resilient to the consequences of those floods.

An issue that received some attention in 1997 and which has troubled transboundary relations is flood control in the lower Pembina River, where local groups are taking the initiative to resolve long-standing transboundary diking and drainage issues. The Commission strongly supports this initiative and has lent the expertise of the Task Force to aid in coming to a common understanding of the technical issues. The Task Force initiated leading-edge laser and radar digital mapping of the area. In addition, it produced special runs of the hydraulic models it has created for the Red River to simulate flooding in the lower Pembina River under alternative flow and flood protection conditions. Local groups are working with Task Force consultants in exploring various scenarios that may help resolve the issues. This and other work the Task Force has undertaken to get at the facts and to find possible solutions for Pembina River flooding are described in this report. The Task Force has also used the basin as a prototype for demonstrating a transboundary virtual database and decision-support system.

Eugene Kozera

Primary Dike

Another flood issue that arose in 1997 concerned high reservoir levels at Lake Traverse and breakout flows on the Little Minnesota River near Browns Valley, Minnesota. These conditions could establish a hydraulic connection between the Mississippi and the Hudson Bay drainage systems and open the way for the migration of alien invasive aquatic species between watersheds. The Task Force examined the probable frequency of inter-basin connection, considered whether flood control infrastructure at Lake Traverse affected the frequency of this connection, and reviewed what might be done to prevent the future transfer of water at this site.

In an effort to gain a better understanding of the flooding issues and in recognition of some weaknesses in technological infrastructure within the basin, the Task Force devoted much of its energy and resources to computer modeling and data issues. The Task Force has created "unsteady flow" hydraulic models that can simulate floodwater flows. These models will be in the forefront of future flood forecasting, floodplain planning and real-time flood fighting. In partnership with the Global Disaster Information Network,* the Task Force established the basis for a virtual database and a decision support system. It will take some time to complete this promising initiative. These efforts will remain as a legacy to aid flood fighters and planners with the latest computer models and information base for effective planning and real-time decision making during flood crises.

Because of the shortfall in funding, the Task Force has had to conclude its work before it could explore all issues in detail and complete its legacy projects. The work accomplished, and the work that still needs to be done on data networking and modeling, are discussed in this report.

Many people in the basin seek institutional changes to deal with flooding and other water issues. The Task Force advocates a two-tier institutional approach. Organizations established within the basin by governments, or perhaps the IJC, would work with grass-roots organizations to ensure that flood-related issues receive the continuing attention they require and to assume responsibility for carrying out the vision that the Task Force sees for preparing the Red River basin for the next major flood.

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* *The Global Disaster Information Network is an interagency initiative within the U.S. government to integrate information relevant to disasters from all sources and to make the information available rapidly and reliably to whoever can take advantage of it to reduce loss of life and damage*

2

Red River Flooding in History

When, in its 1997 report, ***Red River Flooding: Short-Term Measures***, the Task Force warned that a flood of the magnitude of the 1997 flood could happen in any year, it concluded that "flood preparedness must be part of the culture of the Red River valley."[3] Since then, the Task Force has conducted investigations to gain a better appreciation of the frequency and size of major floods. Flood preparedness must begin with an informed understanding of the scale and frequency of flooding that can occur.

Several methods help in extrapolating the early flood history of the Red River. The first is the historical record. The peak calculated natural flow* at the Forks, the junction of the Red and Assiniboine Rivers in Winnipeg, was 163,000 cubic feet per second (cfs) or 4,616 cubic metres per second (cms) during the 1997 flood, including 16,000 cfs (453 cms) from the Assiniboine River. The flow during the 1826 flood, the largest on record, is estimated to have been 225,000 cfs (6,371 cms); in the 1852 flood, 165,000 cfs (4,672 cms). From records kept by the Hudson's Bay Company and other sources, Rannie documented descriptions of the Red and the Assiniboine floods.[4] He concluded that the Assiniboine contributed 30,000 cfs (850 cms) or more to the Red River flood peaks during the 1826 and 1852 floods. Without the Assiniboine, the flow would have been approximately 195,000 cfs (5,522 cms) in 1826 and 135,000 cfs (3,823 cms) in 1852. On this basis, it can be concluded that the 1997 flow on the Red River near Winnipeg was larger than that of 1852 but still substantially smaller than the 1826 flood.

Going beyond the written historical record, sediment deposits at the Forks in Winnipeg and evidence of European settlement can be correlated to nineteenth century floods.[5] These tenuous correlations do not indicate the magnitude of a flood with any precision, but they are instructive. Once it is understood how to relate major sediment deposits to floods, floods farther back in time can be inferred. By applying radiocarbon techniques to date bison bones and other organic materials in sediment layers, it is possible to obtain convincing evidence of flood episodes for over a thousand years, particularly in the 14th century.

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* *In this report, the term "natural flow" means the flow that would have occurred had Winnipeg's flood control structures (Shellmouth Reservoir, Portage Diversion, and Floodway) not been in operation. It is the flow that would have occurred over the current landscape, not the flow that would have occurred prior to landscape modifications by settlers.*

The change from the drier Sub-Boreal Climatic Episode to the moister Sub-Atlantic Climatic Episode around 2900 years ago is marked by evidence of substantial floods at The Forks. The Neo-Atlantic Climatic Episode (ending circa A.D. 1200) was characterized by a warmer, drier climate and only two floods are noted in that portion of the stratigraphic profile, which encompasses more than two hundred years. With the shift to the Pacific Climatic Episode (A.D. 1200 to A.D. 1550), a cooler, moister regimen occurs in the Red River region and five floods are recorded at The Forks within a seventy year period (A.D. 1270 to A.D. 1340).
S. Kroker. 1999 Flood sediments and archaeological strata

Canadian and American scientists are continuing to look for further geological evidence of flooding in the basin. The work should lead to a better understanding of the magnitude and frequency of floods and the geologic processes that influence floods and flood risk. Thirty sites in the valley have been identified in which sediments may reveal flood history. Radiocarbon dating of charcoal found within the deposits indicates 1,200 years of depositional history related to flooding.[6] Scientists are analyzing core samples from three sites, first to identify known historical events, such as the floods of 1997, 1852, and 1826, then to determine earlier flood events.

Analysis of tree rings in samples dating to the mid-1600s may also indicate floods before European settlement.[7] To that end, researchers have established a Red River tree-ring network, extending from Emerson to Winnipeg, with 160 samples from living bur oaks, historical buildings and logs found in sediment deposits. Anomalies in the tree rings have already identified the 1826 flood, and it is expected that this examination will be able to reconstruct earlier climatic and hydrologic events as well.

In other research sponsored by the Task Force, but not yet completed, sediment is being analyzed for biological indicators of previous flooding.[8] Investigators are also looking at two off-channel lakes, normally separated from the Red River but inundated in the 1997 flood, for "diatom signatures." Diatoms are distinctive microscopic algae found in sediments. When found in river sediments deposited in lakes, they differ from those in normal lake sediments. Diatom signatures could indicate flooding in geological time.

Residents of the Red River basin should prepare for floods larger than 1997. The question is, How much larger?

Periods of flooding are often associated with climatic change. Several investigators of post-glacial climate patterns of the Great Plains agree on the climate episodes of the last 2,500 years. The Red River seems to flood more when stronger westerly airflows bring increased precipitation. Possible changes resulting from human activity further complicate the study of climate patterns. A growing scientific consensus sees the increase in atmospheric carbon dioxide in the twentieth century, for example, as contributing to the 0.5°C rise in average global temperatures (0.9°F). While warming could lead to increased precipitation, it is not possible to draw any definitive conclusions as to whether these changes will increase or decrease the number of major floods in the Red River basin.

Climate change aside, the Task Force is convinced that residents of the Red River basin should prepare for floods larger than 1997. The question is, How much larger?

Figure 1

Precipitation and Flooding on the Red River: 1880 to 1998

Manitoba hydrometeorologists have tried to answer the question. They have analyzed the conditions preceding large floods, reviewed the historical record, simulated a series of large floods, and determined the meteorological conditions that could produce such floods.

Five factors determine the size of Red River spring flooding: autumn soil moisture, winter precipitation, rate of spring snowmelt, spring rain, and timing of the south-to-north progression of the melt and rain. Warkentin used these parameters to generate for the Task Force a series of 2,000 simulated floods at Winnipeg.[9] Of these, some 34 natural floods were greater than that of 1997, a figure that accords well with the historical record. Six floods were larger than that of 1826, the largest being about 300,000 cubic feet per second (8,495 cms). Statistical analysis of these generated peaks shows that the 1997 flood was about a 90-year event at Winnipeg; the 1826 flood was about a 300-year event; and the very large flood, a 1,000-year event.* The 1826 flood was not documented in the U.S. portion of the basin and is not therefore the flood of record south of the border.

The analysis described in this section is imprecise and speculative. The evidence, however, is convincing that a flood of the magnitude of 1997 will happen again, as will a flood as large or larger than that of 1826, the most extensive in Canadian history.

Conclusion 1: *Analysis of the geological record, historic floods of the nineteenth century, statistics, and the hydrometeorological factors that cause floods in the Red River basin indicate that floods of the same size as in 1997, or even greater, can be expected in the future.*

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* *This work confirms a study (The Risk of Going Under, 1998) following the 1997 flood by Professor Cas Booy of the University of Manitoba. His statistical analysis of Red River flood peaks, taking into account clustering of peaks, concluded that the probability was high that the 1997 flood would be exceeded in the next 50 years.*

3

Flow Management

The 1997 flood was rare, although it is certain to be equaled or exceeded at some time. Reducing the damage from floods of this magnitude requires improving flood protection measures in the basin, modifying the flow regime to reduce peak flows, or a combination of the two.

The Commission and Task Force heard from a number of residents and experts who strongly believe that the 1997 flood peak would have been reduced if a substantial portion of the runoff had been stored or delayed. If their ideas are feasible, the impact of future floods can be reduced with efforts directed at projects that store or delay peak runoff. There are various proposals for creating more reservoirs, restoring wetlands, and using micro-storage. Others see land drainage as a contributing factor to flooding and seek land drainage limitations.

The Task Force examined these flow management issues as they relate to floods at least as large as that of 1997. The Task Force did not study the effects of flow management on the smaller Red River floods or tributary floods that tend to affect agricultural lands in the spring and summer.

Flood Storage

Record-breaking snowfall during the winter of 1996–1997, capped by a major blizzard in early April 1997, contributed 8 to 10 inches (20 to 25 cm) of water equivalent to the Red River basin for the 1997 flood. That is equivalent to 21 million acre-feet of water in the basin upstream of the Assiniboine River junction at the Forks in Winnipeg (excluding the non-contributing Devils Lake basin). Of that amount, 9 million acre-feet ran off during the spring, while 12 million acre-feet remained on the land, slowly dissipating through evapo-transpiration, infiltration, and release to streams after the flood. Table 1 shows 1997 flood volumes at several main stem locations, according to U.S. Geological Survey, Environment Canada, and Manitoba Conservation figures.

Five dams (Baldhill, Homme, White Rock, Red Lake, and Orwell) account for over 1.0 million acre-feet of flood-control storage. (Because of its headwaters location, Red Lake reservoir's full flood control storage potential is rarely realized.) In 1997 according to the U.S. Army Corps of Engineers, the five reservoirs prevented damages of over $61 million.

Table 1

Flood Volumes at Wahpeton, Fargo, Halstad, Grand Forks, Drayton, Emerson, and Winnipeg

Gage Location	1997 Flood Volume (acre-feet)	Drainage Area (square-miles)	Peak Discharge (cfs)*
Wahpeton	780,000	4,000	12,700
Fargo	1,450,000	6,800	27,800
Halstad	3,400,000	18,000	69,900
Grand Forks	4,900,000	26,000	111,000
Drayton	5,700,000	31,000	124,000
Emerson	6,300,000	36,000	129,000
Winnipeg	9,000,000	45,000	163,000**

* 1 cubic foot per second (cfs) is equivalent to 0.0283 cubic metres per second (cms).
** Calculated natural flow at the Forks (see footnote on page 11)

There are another 280 retention projects, with total storage capacity of almost 0.7 million acre-feet (see Appendix 4).

Of the many dams that can store floodwaters temporarily, most benefit downstream agricultural areas, not communities. The areas below these dams are generally agricultural or undeveloped wildlife areas.

While it is evident that holding back a portion of the peak flow can reduce damage so that existing flood protection works do not fail, the issue is whether there is enough potential storage available at an economically justifiable cost to significantly reduce the damage from rare floods. Several additional storage sites (Table 2) have been identified in past studies. Some of these reservoirs were not built because of economic, social, environmental, or other concerns. These concerns still exist.

Table 2

Sites Where Additional Flood Storage May Be Technically Feasible

Location of Reservoir	Acre-Feet
Wild Rice, MN	44,000
Huot area on Red Lake River, MN	240,000
Bald Hill on Sheyenne, ND	100,000
Maple River, ND	60,000
Upstream of Lake Traverse, MN & SD	75,000
Downstream of Lake Traverse	65,000
Pembina River, ND	110,000
TOTAL	**694,000**

Only a small amount of additional storage is under active development in the basin. For the most part, the figures in Table 2 should be considered as theoretical.

Flood Peak Reduction

The UNET and MIKE 11 unsteady flow hydraulic models developed by the Task Force were used to evaluate additional largely hypothetical storage (see Chapter 11 for a discussion of these models). Some of the storage included the theoretical reservoirs listed in Table 2; in other cases quantities of water were simply removed at key locations. In one UNET scenario, the 1997 tributary flood hydrographs were modified to reflect optimum operation of these reservoirs. Reductions in flood peaks were then calculated for Wahpeton, Fargo, Grand Forks, and Drayton (Table 3). Under these optimal theoretical conditions, water levels are reduced by about a foot at all locations but by over two feet at Grand Forks (0.61 m).

Table 3

Impact of Storage Projects on the 1997 Flood Levels in the United States

	Additional Storage (Acre-Feet)	Water Levels (feet above sea level)		Difference from 1997
		1997	Modeled Value	
Wahpeton	140,000	962.1	961.0	-1.1
Fargo	300,000	901.0	900.1	-0.9
Grand Forks	584,000	833.7	831.3	-2.4
Drayton	584,000	800.6	799.6	-1.0

Similarly, a project undertaken by the Minnesota Department of Natural Resources[10] used a hydrologic model to compute the storage required to reduce the 1997 peak flow at Grand Forks to that of the 1979 flood, that is, from 111,000 cfs (3,143 cms) to 89,000 cfs (2,520 cms). The model used the 1997 daily flow data for April and May. The water was routed through simulated reservoirs of various sizes by trial and error until the predicted peak stage was reduced to 49.0 feet (14.9 m) from the actual 54.2 feet (16.5 m). This reduction required approximately 1.3 million acre-feet of flood storage.

The MIKE 11 model also examined peak reduction scenarios for the Canadian portion of the basin.[11] The simulations removed 100,000, 200,000, and 400,000 acre-feet from the 1997 inflow hydrograph at Grand Forks to test the theoretical effect on downstream water levels. Another storage simulation removed 800,000 acre-feet from the 1997 hydrograph between Grand Forks and Emerson, 75,000 acre-feet of that total from the Pembina River. The model removed the water at optimal times, with no consideration given to possible storage location. In practice, it is unlikely that a storage reservoir could be operated to remove water at optimal times during large floods.

For the 400,000 acre-foot storage removal scenario, the peak water level at Emerson fell to 792.3 feet (241.5 metres) above mean sea level, 0.5 feet (0.15 metres) less than 1997 modeled levels. A summary of the results for all the scenarios is presented in Table 4.

Table 4 indicates that up to 800,000 acre-feet upstream storage reduces 1997 flood levels along most of the main stem of the river in Canada by a little over a foot (0.305 metres). The simulation also confirmed that, for floods of 1997 magnitude, Pembina storage has no effect on Red River levels at Emerson. Upstream storage, however, does have a much greater effect at the Red River Floodway inlet at Winnipeg, where the 25-mile (40 km) wide "Red Sea" narrows to a width of less than one mile (1.6 km). Water levels in this area are sensitive to reductions in streamflow, and storage of 800,000 acre-feet in the upper basin could reduce levels by almost five feet (1.52 metres). Lower water levels at the Floodway inlet could reduce risk to Winnipeg itself. One possible storage site upstream of Winnipeg is discussed in Chapter 5.

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Table 4

Impact of Storage Projects on Flood Levels in Canada

Location	1997	Storage (Acre Feet)				Storage (Acre Feet)			
		100,000	200,000	400,000	800,000*	100,000	200,000	400,000	800,000*
		Modeled Values				*Difference from 1997*			
	Water Levels (feet above sea level)								
Emerson	792.8	792.7	792.6	792.3	791.6	-0.1	-0.2	-0.5	-1.2
Morris	783.2	783.1	783.0	782.7	782.1	-0.1	-0.2	-0.5	-1.1
Ste. Agathe	776.2	775.9	775.8	775.5	774.8	-0.3	-0.4	-0.7	-1.4
Floodway Inlet	771.5	770.1	769.0	767.7	766.7	-1.4	-2.5	-3.8	-4.8

* For the 800,000 acre-foot simulation, the volume was removed between Grand Forks and Emerson. For the others, the water was removed at Grand Forks.

Conclusion 2: *It would be difficult if not impossible to develop enough economically and environmentally acceptable large reservoir storage to reduce substantially the flood peaks for major floods.*

Micro-storage

From the air, the network of section line roadways in the Red River basin looks like a waffle or an ice-cube tray. The visible lines that are the road surfaces represent areas generally higher than the adjacent lands. Culverts restrict the flow of water from these areas, thus providing some unmanaged short-term storage (see Figure 2). There have been proposals to increase flood storage by using the roadways and adjacent land as a series of small low head reservoirs, which can then be controlled by gates on road culverts.[12]

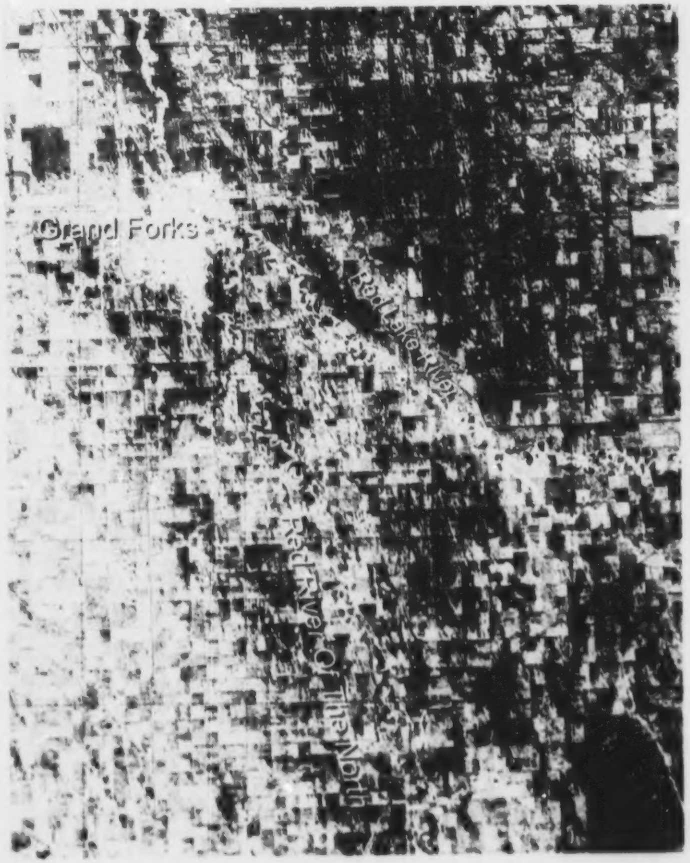
Other options include a passive system in which road culverts would not be gated but would be undersized to retard runoff. Both the active and passive approaches envisage thousands of micro storage sites scattered throughout the basin rather than the flood storage reservoirs discussed earlier.

The principle behind micro storage is that floodwaters can be stored during periods of peak flow and then released. A critical point is that the water stored has to reduce the peak on the Red River, not necessarily on the tributary where the micro-storage is located. Any storage will reduce flow volume, but effective reduction of peak flows requires accurate and detailed forecasts and a sophisticated control system.

One drawback to this type of storage is that controlling local flows would delay the runoff and thus increase the duration of flooding on some lands. This local flooding could be reduced with a detailed plan for separately operating the gates that control water levels in each impoundment.

Figure 2 (a)

19 April 1997 RADARSAT Image



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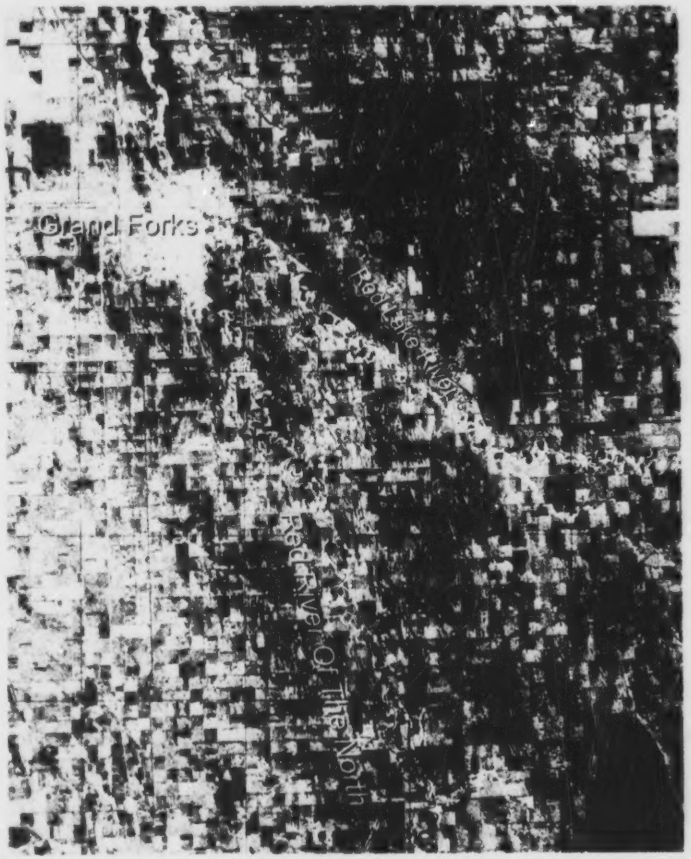
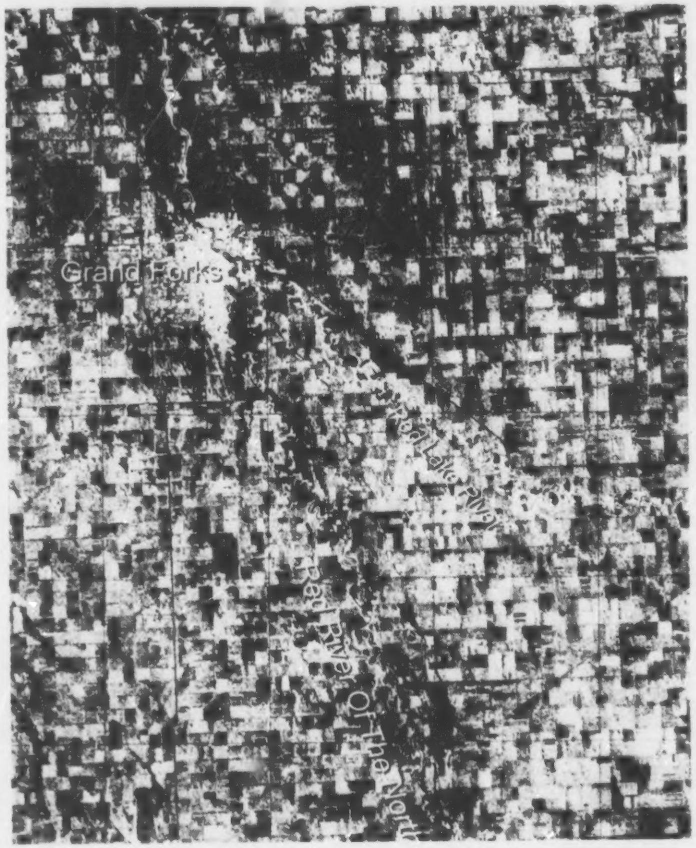


Figure 2 (b)

24 April 1997 RADARSAT Image



Reducing the 1997 flood peak to 49.0 feet (14.9 m) from the actual 54.2 feet (16.5 m) at Grand Forks would have required approximately an additional 1.3 million acre-feet of storage, according to the Minnesota study mentioned earlier. If water could be stored to an average depth of three feet (1 m), that 1.3 million acre-feet storage could be contained on approximately 400,000 acres of land (160,000 hectares), or about 700 square miles (1,800 km^2), all upstream of the point where the flood peak would be reduced. The farther away the distributed storage is from the center needing protection, the more inefficient it becomes. Because of that and because local runoff conditions vary from year to year, achieving the desired flood control effect would require the commitment of well over 700 square miles (1,800 km^2) to micro-storage.

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During large floods, small impoundments tend to fill and spill, thereby delaying the movement of water downstream. This delay affects the timing of the tributary peaks, something that may or may not have a positive effect on the Red River peaks in any given year. To be absolutely certain that micro-storage would not have a negative effect on Red River peaks, water would have to be retained on the land until it was clear that the Red River peak was subsiding, a period of two or three weeks.

Micro-storage would therefore require many infrastructure changes—for example, roads would have to be raised and leveled, and culverts would have to be replaced or gated. To reduce erosion damage to roads, overflow sections would have to be constructed by hardening a section of road. It would also be necessary to design a remotely operated gate that would be ice-proof, rodent-proof, bullet proof, and trash-proof. Buildings on the land used for micro-storage would have to be floodproofed.

Assuming an additional road elevation of about 1.5 feet (0.5 m), current construction costs, and no hardening, the approximate cost of implementing micro-storage would be at least $250,000 a square mile ($96,500 per km^2), provided no major changes would be needed. Other capital costs, and annual operation and maintenance, would be additional. Micro-storage therefore is not inexpensive storage.

In addition, landowners would likely have to be compensated for delayed or foregone planting. Based on recent experience, payments for such storage could range from $20 to $80 per acre per year (roughly $12,000 to $50,000 a square mile) ($50 to $200 per hectare or $5,000 to $20,000 per km^2), depending on the value of the crops. This payment could be required annually, regardless of whether or not the land is flooded. The payment could also perhaps be made as a lump sum flood easement. Determining storage cost payments is critical to establishing the feasibility of any micro-storage proposal.

A detailed plan for separately operating the gates that control water levels in each impoundment could reduce local agricultural flooding resulting from micro-storage. Such control capability would also reduce the possibility of aggravating downstream flooding on the main stem through inappropriate gate operation. Active operation of micro-storage would require an elaborate supervisory control and data acquisition system working in conjunction with a fine-resolution distributed hydrologic model.

The distributed hydrologic model, which would include detailed topography of the flatter portions of the basin, would be used to forecast inflows from various sub-basins and predict the requirements for micro-storage. The control system would open and close individual culvert gates to reduce the peaks on the Red while minimizing local flooding. As the number of storage sites increases, it becomes more difficult to model the system and ensure compliance with optimal operation. The control system would have to operate under one authority immune from local disruption so that the flood control benefits would not be negated.

The operating rules should also account for use of the system in dry years. Such use may benefit agricultural production at the risk of jeopardizing downstream water supplies.

Conclusion 3: *Large-scale micro-storage has some potential to reduce flood peaks on the Red River but is likely to be impracticable and costly. There are many obstacles to its effective and efficient implementation.*

The role of wetlands in the prairie ecosystem is an issue of major importance.

Wetlands

Wetlands influence both water quantity and quality, serving to alter flow regimes and water chemistry. They contribute to groundwater supplies and can modify the effects of local floods and droughts. They also benefit wildlife and serve as valued habitat in regional and even continental ecosystems, for example as resting places for migratory waterfowl. The role of wetlands in the prairie ecosystem is an issue of major importance, which the Task Force was not able to explore. Task Force focus was narrower, the potential for wetlands to reduce the peaks of large Red River floods.

For the purposes of this report, wetlands are defined as shallow depressions in the land that retain water on the surface for longer than a few days. The Task Force looked at wetlands from the point of view of their ability to reduce the flood peaks of large Red River floods.

The early settlers of the Red River basin saw wetlands as a nuisance and an impediment to agricultural productivity. To support them, government programs funded wetland drainage. When roads were built, they had ditches, which drained individual fields and entire wetlands. Government programs also funded the construction of farm impoundments, conservation dams, and flood control storage.

One study undertaken for the Task Force reconstructed the pre-agricultural landscape of the Canadian portion of the basin. Based on surveys in the 1870s, lands were categorized as prairie, woodland, scrub, and wetlands and displayed in a geographic information system.[13] Wetlands comprised 12 percent of that landscape compared to 3 percent in 1998. Reliable figures on wetland drainage for the basin are not available, but it seems clear that the vast majority of Red River wetlands were modified by human activity during the twentieth century.

The Task Force looked at wetlands from the point of view of their ability to reduce the flood peaks of large Red River floods.

Wetlands may retain floodwaters, reducing peak flows or total flood volumes or both. However, the extent to which restoring wetlands can help alleviate floods is controversial. Since little research has been done on this subject in the Red River basin, the Task Force undertook two studies on wetland storage to quantify the potential reduction in flows on tributaries during major floods like the 1997 flood. The work was conducted in the Wild Rice River basin in Minnesota, the Maple River basin in North Dakota, and the Rat River basin in Manitoba.[14]

The studies used a digital elevation model of the three watersheds to define the potential wetland storage volume available, and calibrated a hydrologic model for the current conditions in the basins. Increases in potential wetland storage under a number of scenarios up to a four-fold increase were then applied to the hydrologic model, and the resulting flow conditions were compared to the existing situation. In all three cases, the calculated effect of additional wetland storage on the 1997 peak flow of the tributary was insignificant.

These results are not surprising. In 1997, there was an exceptional amount of snow and water on the land before the 1997 runoff—the highest amount of the century. Virtually every part of the basin contributed to the flow and relatively little additional storage was available.

There are a number of uncertainties associated with these hydrologic studies, including the accuracy of the digital elevation models. A more detailed model may provide better estimates of potential wetland storage. Different storage scenarios might also be used, but the scenarios tested did include large increases in wetland area. Based on the present results, the Task Force believes that it is unlikely that more sophisticated hydrologic modeling would change the general findings concerning effects on large floods.

The influence of wetlands in reducing peak flows for smaller or local floods is another issue. Hydrologic analyses, similar to those conducted for this study, may show that additional wetland storage could lower peak flows during smaller and local floods. This may be particularly relevant to reducing agricultural flooding from summer rains.

The Task Force studies examined the economics of increasing wetland storage.[15] Land can be purchased directly or as a storage easement. Benefit-cost analysis of wetland storage showed that the costs outweighed the benefits to flood control. Environmental and other benefits and costs were not included in the analysis.

Wetland restoration should be evaluated for local benefits and costs, rather than for any basin-wide benefit related to major floods.

The overall findings for the basins studied indicate that the flood control effects of wetland restoration should be evaluated for local benefits and costs, rather than for any basin-wide benefit related to major floods. Overall, benefits are more likely to be associated with ecosystem restoration and wildlife habitat than with control of major floods.

Conclusion 4: *Wetland storage may be a valued component of the prairie ecosystem but it plays an insignificant hydrologic role in reducing peaks of large floods on the main stem of the Red River.*

Conclusion 5: *There may be many good environmental and other reasons to restore wetlands, but wetland restoration is an economically inefficient method of reducing flood damages for infrequent large floods, like the Red River flood of 1997.*

Recommendation 1: *Wetland restoration projects for flood control should be evaluated on the basis of their local benefits and costs rather than imputing a basin-wide benefit.*

Drainage

Drainage of wetlands and agricultural and urban uses of land are often cited as factors contributing to the record 1997 flood. Wetlands and land use can have significant effects on how much water runs off into streams and rivers, and how soon, particularly when climatic conditions are near average or "normal". However, record or near-record winter precipitation over thousands of square miles and the resulting runoff volume in 1997 caused depressions in the land to fill and spill. Wetland drainage and land-use practices likely contributed little to the record flooding.

While drainage has reduced the natural storage capacity within the basin, other offsetting factors increase storage. These include the 1.7 million acre-feet of storage in reservoirs, other retention structures, and the storage effect of the gridded network of roads on detaining water during large floods.

Artificial drainage can be classified into four types, which sometimes operate in combination with each other:

- **Wetland drainage**: Areas of standing water are drained through outlet ditches—there is almost no tile drainage in the basin.
- **Road ditch drainage**: Water drains from the road system and adjacent lands by road ditches.
- **General field, or sheetwater drainage**: Surface water (not water in wetlands) is removed from fields by either ditching or land planing (leveling)—tile drainage is not used for general field drainage in the basin.
- **Water table drainage**: Surface drains lower water tables enough to facilitate farming or other uses of lands with naturally high water tables.

The impact of artificial drainage on flood flows depends primarily on the hydrology of the watershed and cannot be generalized.

Wetland and road ditch drainage account for about 90 percent of drainage volume. Drainage starts with privately constructed drainage (such as ditches or land leveling), that lead to public drains (which are funded in large part by taxes levied on benefiting properties) or road ditches, which enter natural watercourses.

Drainage influences runoff by changing the volume or the timing of flows. Artificial drainage may increase the absolute volume of water entering natural watercourses by adding formerly non-contributing areas to the drainage system. The downstream effect of a change in runoff volume, however, depends on timing of flood peaks.

Artificial drainage moves water more quickly from where it accumulates (either as rainfall or as snowmelt) to a natural watercourse. The change in timing of when water enters a natural watercourse may increase peak flows, cause no change, or decrease the peak flows. During the 1997 flood, tributary peaks tended to coincide with peaks on the main stem, thus exacerbating an already serious situation. The 1997 flood volume at Winnipeg was similar to that of the 1950 flood, but the peak was substantially higher.

The impact of artificial drainage on flood flows depends primarily on the hydrology of the watershed and cannot be generalized. Small-basin studies of drainage show the effects of drainage on peak flows and volumes. Extrapolating those effects to the entire basin is difficult, as peak timing is a major consideration. Removing water quickly from the land may sometimes provide a benefit; in other cases, it may mean that local peaks coincide with main-stem peaks. Drainage is an issue that requires further study.

Effects of Distributed Storage and Drainage on Peak Water Levels

In summary, additional tributary storage would generally achieve modest reductions in water levels for the quantity of water stored, whether in reservoirs, on fields, or in restored wetlands. Its effectiveness would also depend on the timing of release. As well, drainage projects may or may not increase main-stem water levels, depending on the flood in question.

Additional tributary storage would generally achieve modest reductions in water levels for the quantity of water stored.

The analytical challenge is to consider how a series of projects distributed throughout the basin can affect water levels downstream on the Red River itself. This analysis can be accomplished using the distributed hydrologic models discussed in Chapter 11, combined with the Task Force's UNET and MIKE 11 hydraulic models. Some steps have been taken to implement partially distributed hydrologic models on some tributaries, and further work will undoubtedly be accomplished in the future as data needs are met and as funding permits.

These models will increase our understanding of how the basin functions and will provide new insights. They will not, however, reveal any specific storage solution to large floods on the Red River. They are more likely to help identify measures for reducing the impact from smaller tributary floods, such as constructing small impoundments, changing tillage practices, or returning land to permanent vegetative cover.

Another factor that confounds the use of distributed storage to reduce flood peaks along the main stem is the difficulty in managing such storage. Decision-support tools exist to manage operations at multiple reservoirs and predict the downstream effects. However, as the number of impoundments increases, the complexity of the system increases even more rapidly. Actively managing a system having, in effect, hundreds of small reservoirs is fraught with problems and the results are uncertain.

The operation of a distributed reservoir system would likely be too uncertain for urban centers at risk from large Red River floods. The choice is between management of a flood at the point of origin or the relatively more certain prospect of relying on local measures, both structural and non-structural.

Effects of Urban Levees on Flooding

Concerns were raised about the effects on downstream water levels of constructing new levees for Grand Forks and East Grand Forks. Would the risk to downstream communities be increased by the reduction in off-channel storage?

The UNET hydraulic model used to examine effects of upstream storage was adapted to analyze this issue. The model kept urban areas dry until the levees overtopped at the level of the 1997 flood. The storage represented by the flooded cities was simulated at or just preceding the flood peak to provide near-maximum effect on reducing discharges and flood stages downstream. Smaller floods do not overtop the levees. Floods larger than 1997 would overtop the levees sooner and use the available storage well before the peak arrived. Only if the levees were overtopped a few days later than actually occurred would the model show a higher stage increase downstream.

The Grand Forks and East Grand Forks storage areas were filled with water during the 1997 flood calibration modeling. The maximum volume of water stored within these areas at the peak of the flood was 15,000 acre-feet. This quantity is insignificant compared to the large volume of water in the Red River during the 1997 flood. The results on downstream water levels are shown in Table 5.

Table 5

Modeled Stage Increases With no Levees Overtopping

Location	River Mile	Stage Increase above 1997 Flood (Feet)
Letellier, Manitoba	141.17	0.00
Pembina, North Dakota	158.00	0.02
USGS gaging station at Drayton, North Dakota	206.70	0.04
Minnesota Highway 1 at Oslo, Minnesota	271.20	0.04

Ice Jams

River ice can cause property damage, erode stream banks, disrupt transportation and hydropower operations, and make flood forecasting difficult. As of 1999, the U.S. Army's Cold Regions Research and Engineering Laboratory (CRREL) National Ice Jam Database lists 397 events in North Dakota in which ice, particularly ice jams, affected river stages and a further 488 events in Minnesota. Rannie[10] has catalogued similar data from the Canadian portions of the basin. There has been no effort to produce a basin-wide list of ice jams.

Tributaries with significant channel gradients and confined channels are prone to ice jams. Examples include the Sheyenne River from Valley City to upstream of Kindred, North Dakota; the Pembina River above Walhalla, North Dakota; and the Red Lake River from Thief River Falls to Crookston, Minnesota. Ice jams in these reaches can cause rapid and sometimes severe stage fluctuations. Assiniboine River jams can affect operation of the Portage Diversion, part of the flood protection system for Winnipeg. The Winnipeg Flood Protection study, described in Chapter 5, examined this problem.

Main stem conditions differ from those of tributaries in that there is usually a broad, wide floodplain and mild stream gradients. During the initial break-up, river levels can fluctuate greatly as ice jams form, release, and re-form further downstream. Once the river starts to overflow its banks, however, the width available for floodwaters increases dramatically and the ice jam potential is reduced. Generally, the ice dissipates before the peak flood stage.

In 1996, a major ice jam resulted in flooding in portions of Selkirk, Manitoba. As the 1997 flood approached, thousands of holes were drilled in the ice near Selkirk to weaken the surface. No ice jam flooding took place, but the evidence is inconclusive whether that outcome is attributable to drilling.

Getting the Water Moving Earlier

The Task Force heard the theory that peak flows could be reduced if ice were removed from the river channel prior to runoff. This was often phrased as "getting the water moving earlier."

Aside from the potential for creating ice jams by creating an enormous quantity of ice chunks in the river, such a strategy would be ineffective. The quantity of water flowing in the river in one day near the peak can equal one month's flow before breakup.

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Ice Control Using Air-cushioned Vehicles

Under certain conditions, air-cushioned vehicles, such as hovercraft, can create a standing wave capable of breaking up to three-foot thick ice. Generally the ice surface must be free of ice ridges and the vehicle must work from an ice-free open water area. Air-cushioned vehicles are not effective at clearing broken ice. On the St. Lawrence River ice breakers clear the ice broken by air-cushioned vehicles. The air-cushioned vehicles used on the St. Lawrence weigh 120 tons.

A number of structural and non-structural ice management techniques can prevent or reduce the frequency of ice jams. Structural measures are expensive and therefore not cost-effective for Red River conditions. An exception might be channel modifications in communities having a persistent problem at one location. Similarly, ice conditions in the Red River basin generally cannot be controlled by ice suppression techniques, such as bubblers and thermal or flow regime modification.

Two potentially feasible ice-control procedures have been used in the basin. They involve either surface treatment to hasten melt or ice cutting to control break-up. Dark substances applied to the ice surface absorb solar radiation and increase melting. For the greatest ultimate benefit, the substances must be applied well before break-up, but that means the dust could be covered by new snow. The substances used in dusting should be chemically benign. A related technique to hasten melt is to remove snow from the ice surface, as the underlying ice cover will absorb more solar radiation than a snow cover.

Ice cutting is generally considered a technically and economically feasible method of ice control, especially for smaller events. Ice cover can be weakened in locations subject to frequent ice jams through drilling, sawing, or splitting. Caution must still be exercised, however, as there may be potential for problems with disposal of the broken slabs. If they move downstream and lodge, they may cause further problems.

Ice dusting with chemically benign substances and ice cutting appear to have potential as feasible, non-structural, ice management strategies in the Red River basin. Structural measures could be justifiable at locations where ice jams cause frequent and serious damage to property and infrastructure. In all cases, adoption of a mitigative strategy should be based on thorough study of local conditions, and care should be taken to protect downstream interests.

Recommendation 2: ***Future ice jam information from the entire basin should be incorporated into the CRREL Ice Jam Database so that ice problems in the basin can be analyzed further. Where feasible, historic ice jams from the Canadian portion of the basin should be entered.***

4

Communities at Risk

General

Residents and governments at all levels in the Red River Basin recognize the need for flood protection and have been active in taking measures to safeguard business, homes, properties and communities. See, for example, the list of 280 reservoir retention projects in Appendix 4 and the list of local protection measures in Appendix 3. Although the number of projects indicates a strong commitment to safeguard homes, investments, and communities, flood mitigation activities in the basin go well beyond those listed in these tables. Measures also include relocation of homes and businesses out of the floodplain, construction of agricultural levees and ring dikes around rural homes, agricultural practices to prevent rapid runoff, restoration of wetlands, preparation and updating of evacuation plans, and other non-structural flood damage reduction projects. (See Chapter 6 for a more general discussion of floodplain regulation and other policies in place to promote flood mitigation and community resiliency.)

United States Army Corps of Engineers

Pembina, ND

Much more should be done to prepare for floods of a similar magnitude or larger than occurred in 1997. One cannot entirely prevent damage from floods in the basin, but the actions that can be taken need to be evaluated and appropriate resources allocated when proposed improvements are cost-effective.

Local Protection Projects

Many communities protect themselves from floods by retaining runoff before it gets to the floodplain or by removing structures from harm's way. Although these measures are typical and effective, many communities have found levees to be the only economically justifiable and socially acceptable protection measure. Urban levees are appropriate provided they are evaluated systemically, are set back at a reasonable distance from the river, and take account of natural functions of the

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floodplain. If the structural improvements are not engineered to withstand the forces of flooding, the levees are not high enough, or they can not be raised in an emergency, local systems may give residents a false sense of security. In some instances, not all sources of flooding may have been considered, such as "backdoor" flooding, inadequately plugged sewer systems, unknown seepage paths under a levee, inadequate closures at streets and railroads, and interior drainage. Individual community projects must also be evaluated systemically to determine negative consequences outside the community.

Some risk remains even when permanent levees provide a high level of flood protection. Dike elevation design is based on floods of a certain height or frequency. Costs weighed against the damages prevented usually determine the flood frequency to defend against. The new levees in Grand Forks, for example, are designed for a 210-year flood. A greater flood that overtopped the levee would place all people and property of that community in jeopardy, especially if residents were unprepared. The lower the level of protective structures, the more frequently the community is at risk. As part of flood protection preparedness, communities need contingency plans to prepare for the potential overtopping of their levees.

The projects listed in Appendix 3 show that many communities in the United States had temporary levees in place in 1997. Many communities have upgraded their levees since then, some in compliance with federal design standards. These communities qualify for the U.S. Non-Federal Flood Control Works Inspection Program (FCWIP), which encourages construction of non-federal levees to minimum standards. Under the FCWIP, the federal government compensates participating communities for 80 percent of the cost of rehabilitating their flood control works in the event of major flood damage. The state and local governments cover the remaining 20 percent of the cost.

Approximately 70 percent of the communities in the U.S. portion of the basin, do not meet minimal federal standards and are not certified for the FCWIP.

Communities with levees built to federal standards and designed to protect against 100-year floods, including a freeboard allowance, can request certification from FEMA to remove the protected area from the 100-year floodplain. However, levees in approximately 70 percent of the communities in the U.S. portion of the basin, as listed in Appendix 3, do not meet minimal federal standards and are not certified for the FCWIP. While not necessarily inadequate, these levees may have been built under emergency conditions, often in less than ideal weather, quickly, or without engineering. They may or may not be adequate but they are now being relied upon as the only line of protection against floods.

Inclusion in the FCWIP ensures that qualified engineers will inspect the levees on a biannual basis and assist communities in the rehabilitation of flood-control structures damaged by floods. The inspection is at no cost to the community.

Recommendation 3: *Communities in the United States portion of the Red River basin should ensure that community-built flood damage reduction projects are certified by FEMA for 100-year or greater protection, or should participate in the Non-Federal Flood Control Works Inspection Program.*

In Manitoba, $130 million in federal-provincial funds were made available after the 1997 flood for floodproofing. Funds are available for construction of community ring dikes to provide protection to 1997 flood levels. Projects have been undertaken at Ste. Agathe. Feasibility and design work is essentially complete on seventeen additional community diking projects, totaling an estimated $40 million. Construction is scheduled to begin in the summer of 2000 and to be completed by March 31, 2003. The projects include Rosenort, Niverville, Gretna, Aubigny, St. Pierre-Jolys, Lowe Farm, Riverside, Emerson, Rosenfeld, and Dominion City.

Large Population Centers

Winnipeg (population 670,000) survived the 1997 flood, suffering comparatively less damage than some other cities in the basin. However, its flood defenses were stretched to the limit and may prove inadequate for the next flood of similar size or larger. The next chapter examines in detail the risks faced by Winnipeg and alternative measures to reduce those risks. The situation in other basin cities is discussed below.

Fargo/Moorhead (population over 100,000): The record-setting flood crest elevation occurred in 1997 at 39.62 feet (12 m) (elevation 901.42 feet above mean sea level) (274.75 m). A permanent flood control project completed in Fargo in 1961 included four channel cutoffs and a 3,500-foot (1067 m) levee. The design height of the permanent levees in Fargo was to a stage of 41.3 feet (12.6 m); however, with settling, the actual protection is to a 40.0-foot (12.2 m) stage. The West Fargo diversion of the Sheyenne River Flood Control Project, completed in 1993, prevented cross flows from the Sheyenne River from flooding Fargo and West Fargo. Moorhead has no permanent federal flood control project. Both communities avoided major flooding in 1997 by either raising existing levees or building temporary barriers. Since the 1997 flood, both communities have implemented mitigation measures, including the acquisition of almost 100 floodplain homes, raising and stabilizing existing levees, installing permanent pump stations, and improving storm sewer lift stations and the sanitary sewer system.

The City of Fargo is also investigating the feasibility of providing permanent protection to areas on the south side of the city. The height of the permanent flood control projects was exceeded during the 1997 event, and flood barriers built since the flood have not been certified. The current review of the hydrology of the Red River being conducted by the U.S. Army Corps of Engineers and FEMA may alter the 100-year flood level and require revision of FEMA's flood insurance maps for Fargo and Moorhead. The routing of flows representing an 1826 event shows that a flood stage at Fargo/Moorhead would have been 4.6 feet (1.4 m) higher than occurred in 1997*

Grand Forks/East Grand Forks (population 60,000): The maximum stage reached in 1997 was 54.35 feet (16.56 m)(elevation 833.35 feet (254 m) above mean sea level. Temporary levees had been built to stages 52.0–52.5 feet (15.8-16 m) when they were overtopped. Damages from the flood to the cities of Grand Forks and East Grand Forks were estimated to be $3.6 billion[17]. Since the flood, these communities have been working with the U.S. Army Corps of Engineers to develop a plan for setback levees and floodwalls. The proposed $350.3 million project will be constructed between 2000 and 2006 to provide permanent protection for an event having a 210-year frequency of occurrence. The elevation of this barrier would be 838.5 feet (255.6 m) above mean sea level at the primary gage, which is 5.15 feet (1.57 m) higher than the level of the 1997 flood. Since the flood, 571 homes have been acquired in Grand Forks in addition to approximately 520 commercial and residential properties in East Grand Forks. Until the permanent barrier is completed, both communities have taken interim measures, including the raising and stabilizing of temporary levees and improving storm and sanitary sewer systems. With assistance from Housing and Urban Development (HUD), the City of East Grand Forks has also completed a section of removable flood wall in the downtown area. The 1826 flood levels at Grand Forks/East Grand Forks would reach a stage 3.6 feet (1.1 m) above that of the 1997 event, or 1.5 feet (0.46 m below the top of the proposed permanent levee.

Wahpeton/Breckenridge (population 12,000): In Wahpeton, heroic effort and good fortune contained the 1997 floodwaters, which came within inches of overtopping the emergency levees. During the summer and fall of 1997, the city began construction of permanent levees on its own, but a shortage of funds and the desire to have a federally certified flood protection system ended the project before completion. The project was designed for the 1997 flood plus three feet (0.9 m) of freeboard. In Breckenridge, even heroic effort could not prevent approximately $20-25 million of flood damages in 1997. Flooding in Breckenridge is complicated by the fact that damage can occur from either the Red River or the Otter Tail River. At the request of Wahpeton and Breckenridge, the U.S. Army Corps of Engineers began a cost-shared flood reduction feasibility study in June 1999. Preliminary screening of alternatives has now been completed for both cities, and feasible multi-featured flood reduction projects have been identified. Detailed optimization and designs will be completed in July 2000. The federal project is estimated to cost $7 million for Wahpeton and approximately $17 million for Breckenridge. At Wahpeton/Breckenridge, the routing of the 1826 flood results in a stage at 1.9 feet (0.58m) above the 1997 stage.

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* Data on the 1826 flood are limited mostly to Canadian sources, but the U.S. Army Corps of Engineers UNET model has used the information available to simulate a flood of the estimated magnitude of the 1826 flood as it might affect Fargo/Moorhead, Grand Forks/East Grand Forks and Wahpeton/Breckenridge.

Selkirk (population 10,000): The City of Selkirk is the northernmost city on the Red River. The Selkirk Golf and Country Club, the Selkirk waterfront, and a number of storm water outfalls are vulnerable to large floods or from backwater flooding from major ice jams. These areas suffered flooding in 1995, 1996, and 1997. The Selkirk Golf and Country Club is now protected with a permanent dike to a 160-year level of protection plus two feet (0.6 m) of freeboard. The Marine Museum, located adjacent to the river, is also protected to the 160-year level plus freeboard, as is Selkirk Park, located nearby. The city and the Province of Manitoba are currently discussing the design and cost-sharing of protection measures for the storm water outfalls.

Small Communities Where Levees Cannot Be Justified

In the United States, unless a protection project is tied to emergency measures, many projects in small communities do not meet criteria for federal funding. For example, the U.S. Army Corps of Engineers conducted a reconnaissance study to determine federal interest in permanent flood protection for Minto, North Dakota, a town of 600 residents on the Forest River about 30 miles north-northwest of Grand Forks, where 12 homes were flooded in 1997. Only emergency community sandbagging and dike construction prevented more extensive damage. The Corps concluded, however, that the benefit-cost ratio for permanent flood protection was only 0.43, considerably less than the required 1.0 normally required. Without federal interest in this work, flood damage reduction measures will have to rely on state or local initiatives.

Many projects in small communities do not meet criteria for federal funding.

Rural Homes and Farmsteads

Like communities in the United States that cannot meet federal economic criteria for assistance with flood protection, homes and farmsteads in rural areas are often ineligible for U.S. federal funding. Flood protection typically includes constructing individual ring levees, raising structures, or relocating out of the floodplain. Some homeowners have taken their own protection initiatives; those who have not remain susceptible to flooding.

In Manitoba, the federal-provincial program provides assistance for rural residents to raise or floodproof their homes. Under this program, $44.3 million is available for moving, raising or diking individual homes and properties. In 1998, the maximum government contribution for the federal-provincial program increased from $30,000 to $60,000. More than 2,500 homeowners, farms, and businesses are expected to benefit from the increased funding.

Agricultural Land

Although farmers cannot cultivate flooded land, it is not generally economical (at least under U.S. federal funding criteria) to protect agricultural land against spring floods in the Red River Basin. Spring snowmelt (as in 1997) is the source of most large floods in the basin. Such floods cause less economic damage than do the rainfall floods during the

Roads rail lines . . . can have unintended effects by retaining or redirecting flood waters.

growing season that can destroy crops. Recognizing the dependence of the region upon the farm economy, many locally funded agricultural levees have been built. They are typically built to a relatively low frequency level of protection (2- to 10-year flood frequency).

There has been little oversight of the impacts resulting from constructing these agricultural levees. The floodway* now being developed in connection with the update of the Red River profile in the United States will be available as a guide for future use of the floodplain.

Transportation Corridors (Roads, Railroads, Bridges)

Major floods can disrupt transportation. In 1997, the primary north-south highway corridor (Interstate 29 and Provincial Trunk Highway 75) was closed, as was the main east-west corridor (U.S. 2). No bridges were open over the Red River between Fargo and Winnipeg, a distance of over 200 miles. Primary railroad lines were under water, requiring the re-routing of rail traffic. Roads and railroads will continue to get flooded in events like the 1997 flood. Road and rail lines are often raised to reduce the risk of their being flooded. In the flat terrain of the Red River Basin, such construction can have unintended effects by retaining or redirecting flood waters. The raising of any road or rail line must anticipate possible hydraulic impacts.

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* *In the United States, the "floodway" is defined as the channel of a river or watercourse, and adjacent areas. These areas must be reserved in order to discharge a 100-year flood without cumulatively increasing the water surface elevation more than one foot.*

5

Winnipeg at Risk

In 1997, the fate of Grand Forks was very much in the minds of Winnipeg residents as they and emergency management teams, including the military, worked to defend against the rising "Red Sea" to the south. Their efforts included the incredible feat of extending the West Dike by 24 kilometers (14.9 miles) and raising it, all within six days.

Winnipeg, the largest city in the Red River basin, had in place a substantial flood defense infrastructure constructed by the federal and provincial governments between 1962 and 1972. The permanent measures erected during those years included the Shellmouth Reservoir, Portage Diversion, and the Red River Floodway. The primary diking system within the city was constructed following the disastrous 1950 flood. In 1997, all these measures, coupled with enormous human effort and good fortune, succeeded in saving the city from the fate of Grand Forks. But Winnipeg had a close call. In a future flood of the magnitude of 1997 or larger, the city may not be so fortunate. A flood equal to the flood of record in 1826 could lead to the evacuation of at least 300,000 people and cause damages of as much as $5.8 billion.

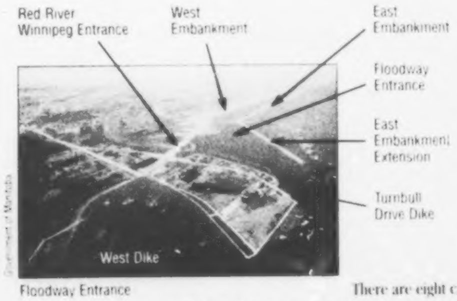
Winnipeg had a close call. In a future flood of the magnitude of 1997 or larger, the city may not be so fortunate.

Winnipeg faces a number of threats from large floods. Of particular concern are:

- possible overwhelming of the design capacities of the overall flood protection system;
- capacity limits of the flood protection infrastructure when flood stages approach or exceed those experienced in 1997;
- wind and wave conditions at the West Dike of the Red River Floodway; and
- lack of comprehensive emergency plans for extreme floods.

To assess the vulnerability of Winnipeg, the Task Force investigated flood risks in collaboration with the Province of Manitoba and the City of Winnipeg. A Winnipeg engineering firm was contracted to do the study.[18] The work included:

- identifying the capacities and vulnerabilities of Winnipeg's flood protection system;
- examining new structural measures or operational changes to increase protection; and
- conducting pre-feasibility engineering of selected measures.



Vulnerabilities

The study identified 57 ways in which Winnipeg is vulnerable to large floods. Many are generic, so the number of potential individual failures is much larger. For example, failure of Floodway bridges is one vulnerability, but it includes 13 bridges. The consequence of a failure also varies—failure of a pumping station is clearly less significant than a breach of the West Dike.

There are eight categories of vulnerability. The study identifies and describes the inadequacies within each, along with the consequence of failure, the level of concern, additional work required to further define the vulnerability, and the priority for further study. High priority areas where the consequences of failure are severe were studied extensively, while some low priority areas were simply identified. A panel of experts provided advice on identifying vulnerabilities and possible mitigation measures.

1. **Overall Flood Protection System.** These vulnerabilities include limitations on the overall capacity of the flood control system, inadequate detailed emergency preparedness and response plans, floodplain development that limits flexibility and may affect public safety, and flood monitoring concerns.

2. **Red River Floodway Inlet Structure.** If the embankments near the inlet structure erode or fail, floodwaters could bypass the inlet. The control system could fail in ways that would make it impossible to control gates—for example, fire in the inlet structure. Other issues include damage from ice, debris, or sabotage, and the need for clarity and understanding of the operating rules.

3. **Red River Floodway Channel.** Bridge failures could restrict the Floodway capacity. The embankments could fail. A failure of the Seine River Syphon could breach the West Embankment of the Floodway and allow an uncontrolled flow of up to 15,000 cfs (425 cms) to enter the city from the Seine River. Many services, such as water and electricity, are vulnerable under certain circumstances as they cross the Floodway channel, but that risk appears low.

4. **West Floodway Embankment.** If any portion of the first three miles (4.8 km) of the West Embankment (between the Floodway itself and the city) is breached, an uncontrolled flow of water would enter the south or east side of Winnipeg.

5. **West Dike.** Failure of the West Dike (the long dike extending from the Floodway Inlet Structure toward the town of Brunkild) through wind action, overtopping, or other causes would lead to uncontrolled flows into south Winnipeg by way of the La Salle River.

6. **Flood Protection Infrastructure within Winnipeg.** The city itself is subject to a number of internal vulnerabilities. These relate to the primary and secondary diking systems and to the flood-pumping stations and floodgate chambers. When river levels are high, floodwater can enter the city through the storm water or sanitary sewer system. There is no guarantee that the many temporary measures taken during the 1997 flood would be as successful again, even for a flood of the same magnitude.

7. **Portage Diversion.** The major threat is that the break-up of ice jams upstream of the diversion reservoir could cause a surge of ice and water and damage the system. Failure of the system for any reason could reduce the flow diverted to Lake Manitoba and hence increase flows toward Winnipeg.

8. **Shellmouth Dam.** The gates could fail, or the dam could breach or fail from erosion. While a Shellmouth dam failure would have severe consequences immediately downstream, the effect on flood protection levels in Winnipeg would be relatively minor.

Ultimate Capacity of the System

The study found that the flood protection system has a reliable capacity through Winnipeg of 71,000 cfs (2,010 cms). In 1997, the flow was 80,000 cfs (2,265 cms). This judgment was based on a safe water level in the city. Calculations of the shortfall in reliable capacity of the channel through Winnipeg are offset by increases in Floodway capacity. The Floodway could operate reliably beyond its 60,000 cfs (1,700 cms) design capacity to handle 73,000 cfs (2,067 cms). Consequently, water levels upstream of the Floodway inlet would rise above natural levels. Finally, the Portage Diversion and Shellmouth Dam can reliably meet their respective design capacities of 25,000 cfs (708 cms) and 7,000 cfs (198 cms).

Theoretically, the ultimate reliable capacity of the system is 176,000 cfs (4,984 cms), somewhat higher than the design capacity of 169,000 cfs (4,785 cms) or the 1997 flood rate of 163,000 cfs (4,616 cms). More refined analysis of complex wind effects on the "Red Sea" may alter that figure. Providing this level of protection would raise water levels at the inlet structure above natural levels. Moreover, extreme floods on the Red River rarely coincide with extreme events on the Assiniboine. In 1997, for example, the maximum flood control capability of the Portage Diversion was not needed.

The flow through Winnipeg in 1997 exceeded the reliable system capacity

The flow through Winnipeg in 1997 exceeded the reliable system capacity (see Table 6). The city was fortunate, but it cannot realistically expect such a favorable outcome every time. On reviewing the vulnerabilities of the flood protection system in Winnipeg and its reliable capacity, the Task Force finds:

Conclusion 6: *Under flow conditions similar to those experienced in 1997, the risk of a failure of Winnipeg's flood protection infrastructure is high.*

Table 6

Capacities of Winnipeg Flood Protection System in Cubic Feet Per Second (cfs)*

Component	Design capacity	1997	Reliable capacity
Shellmouth Reservoir	7,000	4,000	7,000
Portage Diversion	25,000	11,900	25,000
Floodway	60,000	67,100	73,000
River Channel	77,000	80,000	71,000
Totals	**169,000**	**163,000**	**Up to 176,000**

* 1 cubic foot per second (cfs) is equivalent to 0.0283 cubic metres per second (cms)

Flood Damage Estimates

The consultants used Geographic Information System methodology along with U.S. Army Corps of Engineers and Canadian guidelines to estimate flood damages for various floods up to a 1 in 1000 year flood.[19] They considered several direct and indirect sources of damage, mainly damage to residential and other buildings, damage to infrastructure, temporary relocation costs, and flood fighting and emergency response costs. The 1997 flood cost of $67 million in Winnipeg was used as the base case.

Damage estimates were based on a Digital Elevation Model (DEM) that defines the topography of the land and water surface elevations associated with various floods, plus depth damage curves for various types of structures. The depth of inundation—the difference between the water surface and the land surface—was applied to the depth damage curve to produce a building damage estimate. Other damages were calculated by examining damages in Grand Forks in 1997 and projecting those damages to the Winnipeg situation. The results are summarized in Table 7.

Table 7

Estimated Flood Damages for City of Winnipeg ($ millions)*

Type of Damage	1:90 Year (1997) (163,000 cfs) No Flooding	1:90 Year (1997) (163,000 cfs) With Flooding	1:200 Year (1826) (225,000 cfs)	1:500 Year (250,000 cfs)	1:1000 Year (295,000 cfs)
Residential (structures/contents)	9	200	2200	4,070	8,280
Commercial (structures/contents)	0	110	700	2,360	4,560
Temporary relocation costs	-	250	820	950	1,080
City infrastructure impacts	17	160	1460	2,200	2,710
Flood fighting / emergency response	41	41	490	730	900
Additional transportation costs	0	0	100	150	200
Totals	**67**	**761**	**5,770**	**10,460**	**17,730**

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Flood Protection Levels

What level of flood should be planned for—the 1997 flood, the 1826 flood of record, or some theoretical event, such as a 500 year or 1000 year flood? The 1997 flood would have produced a natural flow through Winnipeg of 163,000 cfs (4,616 cms). The 1826 flood is considered to have had a peak flow of 225,000 cfs (6,371 cms), approximately equivalent to a 1:300 flood. A large flood that could reasonably be expected to occur, calculated by combining hydrometeorological variables that are extreme but not individually unprecedented, was about 300,000 cfs (8,495 cms).[20] This coincides closely with the 1000 year flood.

In the Netherlands, flood protection along major rivers is designed for a 1:1,250-year event

Some jurisdictions base flood protection on such rare events when the risk of flooding will have enormous consequences. In the Netherlands for example, flood protection along major rivers is designed for a 1:1,250 year event, and 1:10,000 for coastal storm surges. The flood frequency of design floods depends on location, but the standard in most jurisdictions is a rare event, with return periods up to several hundred years. In Canada, for example, British Columbia uses the 1:200 flood and Saskatchewan uses the 1:500 flood.

A 1:100 year flood has a one percent probability of occurring each year. This annual probability can be converted mathematically to calculate the probability of recurrence over specific periods. For example, there is a 22 percent probability that a 1:100 year flood will occur in the course of 25 years, the length of a typical residential mortgage. The same flood has a 39 percent probability of occurring over a 50-year period. On the same basis the current reliable capacity of the Winnipeg flood protection works has a 37 percent probability of being exceeded at least once in the next 50 years.

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	No Flooding	*With Flooding*			
Residential (structures/contents)	9	200	2200	4,070	8,280
Commercial (structures/contents)	0	110	700	2,360	4,560
Temporary relocation costs	-	250	820	950	1,080
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Given the concentration of Manitoba's population in Winnipeg and the importance of the city to the provincial economy, higher levels of flood protection are desirable. As a minimum, it is reasonable to provide protection against a known event, such as the flood of 1826.

> **Recommendation 4:** ***The design flood used as the standard for flood protection works for Winnipeg should be the highest that can be economically justified or, at a minimum, the flood of record, the 1826 flood.***

Mitigation Measures: Structural

To overcome the vulnerabilities, more than one hundred mitigation options were identified. These options addressed many vulnerabilities besides lack of hydraulic capacity.[21] Structural options related to improving hydraulic capacity include:

- expanding the Red River Floodway;
- twinning the Floodway;
- raising Floodway bridges;
- modifying the east embankment of the Floodway;
- raising primary dikes;
- raising the West Dike and west embankment of the Floodway;
- constructing a Ste. Agathe Detention Structure;
- improving the river channel downstream of Winnipeg;
- implementing a pump scheme at the Floodway inlet; and
- diverting the eastern tributaries of the Red River.

Other Ideas

The study considered two public proposals for increasing the discharge capacity of the Floodway Channel: remove the outlet structure and lower the inlet weir crest level.

Analysis shows that removing the outlet structure could produce a minor increase in flow capacity of 2,000 cfs (56.6 cms) but at the potential cost of significant erosion. Removal cannot be justified.

Lowering the inlet weir crest level by 7 feet (2.13 m) to the level of the Floodway channel would increase the discharge capacity by 50 cfs (1.4 cms). This benefit is insignificant and not worth the complications arising from early entry of ice into the Floodway channel.

Assessment of these projects was based on the degree to which they improve the ultimate capacity of the flood protection system, their approximate costs, and their potential benefits. Any proposed project must be socially and environmentally acceptable as well as technically feasible and cost-effective. The last three projects listed were eliminated from detailed consideration as economically unattractive and technically limited: the channel improvements and eastern tributary projects were environmentally unacceptable. The remaining projects have been subject to pre-feasibility engineering studies.[22] The findings of these studies will be adjusted as acceptable projects advance to the design stage.

Red River Floodway Expansion. The design capacity of the Red River Floodway is 60,000 cfs (1,700 cms) flowing from the inlet at an elevation of 770.25 ft. (234.7 m). With the present bridges, the channel is capable of a flow of up to 92,000 cfs (2,605 cms) at 778 feet (237.1 m). This level, however, cannot accommodate wind effects on the Red Sea or minimize the risk of overtopping of the West Dike. As indicated, the present reliable ultimate capacity is 73,000 cfs (2,067 cms) at 774 ft. (235.9 m). Increases in discharge capacity above 73,000 cfs could be achieved by expanding the discharge capacity of the Red River Floodway channel. Fourteen options involving various combinations of width and depth increases have been studied.

For pre-feasibility studies, it is neither necessary nor appropriate to optimize channel design. For economic comparisons, however, various options were studied to identify a channel configuration reasonably close to optimum.

To accommodate increased flows for an expanded Floodway, the outlet structure would require modification. The inlet structure would not change but its operating rules would need review and modification. Many of the structures that cross the Floodway would have to be altered. These include road and rail crossings, hydro lines, gas pipelines, and hydraulic structures adjacent to the Floodway channel.

The consultant's economic analysis shows that the optimum net benefit is achieved by increasing the Floodway by approximately 75,000 cfs (2,100 cms). This would increase the ultimate reliable capacity for protection of Winnipeg from 176,000 cfs (4,984 cms) to approximately 250,000 cfs (7,079 cms). The optimum channel configuration increases both depth and width. This would increase flood protection for Winnipeg from the existing approximately 1-in-100-year level to a 1-in-500-year level. Larger increases in floodway capacity are probably not feasible, as the backwater from the north would extend into the city significantly above the height of the primary dikes. Even this expansion would require permanently raising the Primary Dikes on the north side of Winnipeg by about 3.5 feet (1.07 m). The West Dike would also be raised as part of the project.

This would increase flood protection for Winnipeg from the existing approximately 1-in-100-year level to a 1-in-500-year level.

Expanding the Floodway is a major project, as large as the original construction, and would take several years to complete.

Red River Floodway Twinning. An analysis similar to that of floodway widening was conducted for twinning the Floodway. The analysis indicated that, while technically feasible, it would cost as much as 30 percent more than Floodway expansion.

Raise Floodway Bridges. The 13 bridges over the Red River Floodway were designed in the mid-1960s for the 60,000 cfs (1,700 cms) design flow of the Floodway. The varying heights of bridge girders above the channel are largely determined by the elevations of the road and rail approaches that existed at the time. As the Floodway flow reaches approximately 70,000 cfs (1,982 cms) (corresponding to a water level of 772 feet (235 m) at the Floodway inlet), some girders start obstructing the flow

Eight of the Floodway bridges obstruct flows higher than the design capacity. At a water level corresponding to 778 feet (237 m) at the Floodway inlet, the bridge decks impede flow and reduce potential capacity by up to 11,000 cfs (311 cms). This reduction does not include other potential effects due to displacement of the decks or ice or debris jamming against the bridge and backing up water.

Three scenarios to raise bridges were examined:
- Raise all the bridges that obstruct high flows; or
- Raise the six bridges at the upstream end of the Floodway; or
- Raise only the St. Mary's and PTH 59 South road bridges and the CPR Emerson line rail bridge.

The first two options, at a water level of 774 feet (236 m), allow a 4,000 cfs (113 cms) increase in flow, the latter a 3,000 cfs (85 cms) increase. Raising the West Dike and allowing the water level to rise to 778 feet (237 m) would provide a benefit of up to 11,000 cfs (311 cms) in the first scenario and 6,000 to 8,000 cfs (170 to 226.5 cms) under the latter two.

High-flow conditions require emergency measures to protect the bridges vulnerable to submersion. Hydraulic loading caused by submersion can shift and in some cases push bridge decks off their piers, creating unpredictable backwater effects. It is proposed to ballast the bridges or lock down the bridge decks to prevent shifting.

Bridge modifications would be part of any Floodway expansion project.

Modify East Embankment of Floodway. The east embankment of the Floodway and the Turnbull Drive dike constrain the flow in the approach to the Floodway inlet. Reducing the length of the embankment protruding into the river or excavating a portion to allow flow directly into the Floodway downstream of St. Mary's Road could lower water levels upstream of the constriction by up to half a foot (0.15 m). The cost would be modest. Preliminary economic analysis showed a relatively high benefit-cost ratio but a relatively small improvement to hydraulic capacity, in the order of 2,000 cfs (56.6 cms). Detailed analysis now under way will determine whether the project poses an additional risk to the flood protection system. If the project proves technically feasible, it could be an economic short-term measure to improve Floodway performance or be incorporated into future Floodway expansion.

Winnipeg Infrastructure Improvements. Approximately 75 miles (120 km) of primary dikes, supplemented by largely temporary secondary dikes, hold the Red River at bay within the boundaries of Winnipeg. Some of the primary diking system, however, is lower than the flood protection level specified by legislation enacted in 1980, which is equivalent to 27.8 feet (8.47 m) at James Avenue. The reliable top elevation is actually 26.5 feet (8.08 m), the level to which they were constructed in the 1950s. An examination of the feasibility of raising the dikes six feet (1.8 m) above the flood protection level to allow increased water levels in the city showed that the proposal had little merit. The cost of raising the primary dikes is high relative to the benefits gained. For the most part, the dikes form part of the city's road network. Modifications would also be needed to bridges, underpasses, and the internal drainage system.

These complexities could mean that a more modest increase in dike height may be feasible in some areas. Once the measures for protecting Winnipeg from future floods have been determined, this can be examined in more detail.

The primary diking system is penetrated in many places to provide sewer and land drainage to areas protected by relatively insecure secondary dikes or no dikes at all. In addition, numerous ungated sewers, channels, and streams flow by gravity to the river. These are temporarily plugged during floods, but such plugs are prone to failure. Moreover, rain during a flood could trap water behind dikes. Resolving these problems and reducing risk to the city requires significant modifications to sewer and land drainage systems. These modifications are costly and should be optimized and undertaken once the overall plan for Winnipeg flood protection is determined.

Projects that provide benefits under conditions of high river levels have been treated as a single protection measure, which essentially provides flood protection benefits to the city from a level of 20.5 feet (6.25 m) at James Avenue to 25.8 feet (7.86 m). This reduces the risk of failure of parts of the system and could correspond to an increase in reliable capacity of up to 20,000 cfs (566 cms) in Winnipeg. For the benefit-cost analyses, these measures have been subdivided into two levels of protection:
- Projects providing protection up to 23.0 feet (7.01 m)
- Projects providing protection between 23.0 feet. and 25.8 feet (7.01 and 7.86 m)

This allows an evaluation of the merits of increasing the reliable flood protection capacity to 25.8 feet (7.86 m) in two distinct increments, with costs representing each level. Once the appropriate flood protection level for Winnipeg has been agreed upon, the appropriate protection against high river levels and required modifications to the internal drainage system can be determined.

Raise West Floodway Embankment and West Dike. The vulnerability analysis concluded that the freeboard allowance of two feet (0.6 m) on the West Dike is too low. Six feet (1.8 m) of freeboard when the Red Sea is at 774 feet (236 m) at the Floodway inlet is more appropriate. When flood waters reach 778 feet, (237 m) the study estimated that eight feet (2.4 m) of freeboard is needed. These freeboard estimates could change after further study. Based on current knowledge, a scheme for raising the west floodway embankment and West Dike by three to six feet (0.9 to 1.8 m) was devised.

The Ste. Agathe Detention Structure would protect Winnipeg up to the 1000-year flood.

The pre-feasibility study used six feet (1.8 m) of additional dike height because water levels greater than 778 feet (237 m) at the Floodway inlet would require costly modifications to the Floodway inlet control structure. Raising the west dike is an essential step in any program to improve flood protection. This could raise water levels upstream of the inlet to be above the natural level and, hence, affect upstream residents. Wind set-up on the "Red Sea" is currently being analyzed. The study will determine the required freeboard and the amount by which the dike must be raised. Raising the West Dike would also provide a short-term benefit to Winnipeg flood protection. Revisions to the Floodway operation rules would also have to be considered.

Ste. Agathe Detention Structure. This is a 25-mile-long (40 km) earth dike across the valley south of Ste. Agathe, connected to a raised west dike and a control structure on the Red River capable of passing flows equal to the 1997 flood without undue restriction. When the flow becomes greater than the present capacity of the Winnipeg flood protection system (approximately at the 1997 flood magnitude), gates on the river would detain water temporarily on lands upstream.

The Ste. Agathe Detention Structure would protect Winnipeg up to the 1000-year flood. It would also reduce flood damages for the residents located between the project and the Red River Floodway inlet. The structure would operate only for floods above the 1997 level. The retention of flow would increase water levels south of Ste. Agathe. Water levels at Morris could increase by about one and a half feet (0.5 m) and six feet (1.8 m), respectively, for the 1826 flood and 1000-year flood. Increased water levels would diminish upstream, likely becoming zero at the international boundary.

It should be a condition for proceeding that the project must increase the level of flood protection for communities and individuals upstream of Ste. Agathe and compensate those who may be affected. A combination of measures would likely be needed.

The structure would have environmental consequences, in particular obstruction to navigation and fish passage. As a result, boat lift and fish passage facilities would be incorporated into the design of the river control structure to reduce these effects. In addition, culverts would be installed in the dike to allow the Rat and Marsh rivers to follow their usual course during normal times. During floods, the peak flows would be diverted by a constructed diversion channel to the Red River.

The Ste. Agathe Detention Structure would be a major project requiring several years to develop. It would provide Winnipeg and areas south of the city to Ste. Agathe with greater flood protection than an expanded Floodway, and at a lower cost.

Table 8

Comparison of Ste. Agathe and Floodway Projects

Project	Protection Level (cfs)*	Present Values ($ millions)			Risk of Exceeding Capacity in Next 50 Years (%)
		Cost	Benefits	Net Benefits	
Raise West/East Dikes + Modify Bridges + Expand Floodway	250,000	770	1,500	730	10
Ste. Agathe Structure + Improvements in City of Winnipeg flood Protection Infrastructure	300,000 +	475	1,900	1,425	5 (for capacity to 300,000 cfs)

* 1 cubic foot per second is equivalent to 0.0283 cubic metres per second

Selection of Best Options. The Task Force analysis indicates that the preferred projects to protect Winnipeg against very large floods are:

- expanding the Red River Floodway, or
- constructing the Ste. Agathe Detention Structure.

The Ste. Agathe project is much less costly to construct but has greater social and environmental implications. Table 8 compares these two large projects.

Floodway expansion would require more improvements to the internal drainage system than the Ste. Agathe Detention Structure, and that cost differential is not reflected in these costs. The figures for the Ste. Agathe project include the present value of estimated average of future damages in upstream areas, but do not include the cost of flood easements.

Smaller projects, individually or in combination, would increase the current level of protection, but could not economically protect against the 1826 flood. These smaller projects include raising the West Dike and west Floodway embankment, modifying the Floodway's east embankment, and raising some of the upstream bridges on the Floodway. After the decision on project selection, the city's infrastructure would need to be modified. Table 9 summarizes the preferred options, their effects on reducing risk, and their costs and benefits.

These projects have undoubted environmental consequences and would have to be constructed subject to and in accordance with the environmental laws of Canada and Manitoba. Expanding the Floodway, constructing the Ste. Agathe Detention Structure, and raising the West Dike would require a detailed review that could best be accomplished under a cooperative federal-provincial process.

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Raise West/East Dikes + Modify Bridges + Expand Floodway	250,000	770	1,500	730	10
Ste. Agathe Structure + Improvements in City of Winnipeg flood Protection Infrastructure	300,000 +	475	1,900	1,425	5 (for capacity to 300,000 cfs)

* 1 cubic foot per second is equivalent to 0.0283 cubic metres per second

Selection of Best Options. The Task Force analysis indicates that the preferred projects to protect Winnipeg against very large floods are:

- expanding the Red River Floodway, or
- constructing the Ste. Agathe Detention Structure.

The Ste. Agathe project is much less costly to construct but has greater social and environmental implications. Table 8 compares these two large projects.

Floodway expansion would require more improvements to the internal drainage system than the Ste. Agathe Detention Structure, and that cost differential is not reflected in these costs. The figures for the Ste. Agathe project include the present value of estimated average of future damages in upstream areas, but do not include the cost of flood easements.

Smaller projects, individually or in combination, would increase the current level of protection, but could not economically protect against the 1826 flood. These smaller projects include raising the West Dike and west Floodway embankment, modifying the Floodway's east embankment, and raising some of the upstream bridges on the Floodway. After the decision on project selection, the city's infrastructure would need to be modified. Table 9 summarizes the preferred options, their effects on reducing risk, and their costs and benefits.

These projects have undoubted environmental consequences and would have to be constructed subject to and in accordance with the environmental laws of Canada and Manitoba. Expanding the Floodway, constructing the Ste. Agathe Detention Structure, and raising the West Dike would require a detailed review that could best be accomplished under a cooperative federal-provincial process.

> *Since the Ste. Agathe project would raise upstream water levels, this project would need to demonstrate the effects, if any, on water levels at the international boundary.*

Since the Ste. Agathe project would raise upstream water levels, this project would need to demonstrate the effects, if any, on water levels at the international boundary. Construction and operation of projects that increase water levels at the boundary require an IJC Order of Approval or an international agreement. In any case, appropriate notification and consultation with the U.S. and state governments must be pursued if this project is to be selected.

Table 9

Summary of Preferred Options for Increased Security of Flood Protection

Measures to Achieve Protection	Flood Protection Effectiveness (cfs)*	Present Values (millions $)			Risk of Exceeding Capacity in Next 50 Years (%)
		Cost	Benefits	Net Benefits	
0 Existing system	176,000	-	-	-	37
1 Modify east embankment at Floodway entrance	to 178,000	2.5	68	65	34
2 1 + Raise West Dike and west embankment	to 194,000	50	475	425	24
3 2 + modify 6 bridges over Floodway	to 200,000	165	590	425	22
4 3 + Improve flood protection infrastructure in Winnipeg	to 209,000	240	640	400	20

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> *Public safety requires immediate attention by the city, province, and federal governments to design and implement measures to further protect Winnipeg.*

Coordinated Action

Public safety requires action to reduce risk as quickly as possible. This will necessitate immediate attention by the city, province, and federal governments to design and implement measures to further protect Winnipeg.

The Task Force recommends a two step approach. The first would be to secure Winnipeg against a flood of the size of 1997, but assuming adverse weather conditions and subject to potential failures. In 1997, Winnipeg benefited from unusually favorable weather after the early April blizzard—light winds, no rain. Rushed temporary measures did not fail. The city cannot always expect to be so fortunate.

Recommendation 5: ***Based on results from hydraulic model studies, modify the east embankment of the Floodway to improve the performance of the Floodway entrance to lower upstream water levels and increase capacity.***

Recommendation 6: ***The west dike should be raised to allow a water level elevation of 778 feet at the Floodway inlet structure with appropriate freeboard.***

Recommendation 7: ***The primary diking system should be raised where economically feasible to the elevation specified in existing legislation.***

In addition to these measures, a major project is needed to increase flood protection for Winnipeg. Both the Ste. Agathe Detention Structure and Floodway expansion can achieve a high level of protection at reasonable cost, although the Ste. Agathe structure is much less expensive and can provide a greater degree of protection. To some extent both projects would raise upstream water levels over natural levels for floods larger than 1997. These large projects will require extensive public and environmental review to determine their acceptability.

Recommendation 8: ***The City of Winnipeg, the Province, and the federal government should cooperatively finance detailed feasibility studies of the two major projects that would protect Winnipeg against very large floods.***

Recommendation 9: ***The three jurisdictions should work towards a Winnipeg Protection Agreement to finance the development of a long-term protection plan that would include construction of the Ste. Agathe Detention Structure or Floodway expansion.***

Recommendation 10: ***Modifications to the sewer and land drainage systems should be optimized and undertaken once the overall plan for Winnipeg flood protection is determined.***

Mitigation Measures: Non-structural

Some important protective measures are non-structural. Of immediate concern is Winnipeg's emergency preparedness. The response in 1997 was heroic, but more planning needs to be undertaken to prepare for extreme events. Manitoba jurisdictions are required to have detailed Emergency Preparedness and Response Plans (EPRP). The EPRPs lay out in detail the best response to all foreseeable failures. The plans include notification charts, inundation maps to guide emergency evacuation, and other information to improve responses in an emergency. For Winnipeg, the flooding component of the plan should include:

- emergency evacuation of large portions of Winnipeg;
- emergency response to breaches in flood-retaining structures;
- emergency construction of approximately 50 miles (80 km) of temporary dikes; and

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- emergency evacuation of large portions of Winnipeg;
- emergency response to breaches in flood-retaining structures;
- emergency construction of approximately 50 miles (80 km) of temporary dikes; and

- operation of flood control works when unprecedented conditions require engineering decisions that are difficult to make without methodical pre-planning.

The current effort by the city to assemble and document emergency procedures needs to be expanded and coordinated with the Province of Manitoba and the federal government.

Recommendation 11: ***The City of Winnipeg should give immediate high priority to the preparation of a detailed emergency preparedness and response manual.***

Other prudent measures that should be undertaken include correcting sewer cross-connections, improving the land drainage system, data acquisition and modeling, and combined and separate sewer operations.

Improvements to the flood protection system will necessitate a further examination of the rules for operating flood control structures. If the Floodway is to be expanded, it would be feasible and perhaps necessary to maintain water levels below the state of nature during medium-sized floods, such as those of 1979 or 1996 and above natural levels for large floods. Construction of the Ste. Agathe Detention Structure would require a completely new set of operating rules for it and the Floodway. Those rules should form the basis for protecting or compensating upstream residents.

Recommendation 12: ***Operating rules for new flood control measures should be designed to accommodate all flow regimes, even those beyond design capacity. The public should be consulted on any proposed new operating rules.***

6

Flood Preparedness and Resiliency

Residents of the Red River basin must prepare for flooding. They must defend against flooding where possible and become resilient to the effects of flooding where they cannot avoid it. Resilience is the ability to bounce back or adapt quickly to the consequences of an extreme natural event, such as a flood. Many activities, techniques, and measures that reduce the effects of future floods promote flood resilience. They include accurate and timely warnings, flood control measures, the designation of flood-prone areas as open space, flood insurance, flood-resistant construction, and storm-water management.

The previous chapters reviewed a number of structural measures that are being taken in the Red River basin or that can be taken to defend against flooding. However, many communities and residents will still remain at high risk from major floods. To supplement structural measures, communities will have to implement other measures to keep the impact of flooding low and to give residents the ability to adapt quickly to the consequences of a flood.

Figure 3 highlights many of the elements of a resilient basin. For example, in a flood-resilient basin, riparian areas are in natural or restored condition, with no paved channels. There is little threat of flood-induced pollution. Flood-resilient infrastructure and housing reduce the risk to buildings. Residents understand the risks, are adequately insured, and know what to do when a flood threatens. Business is sufficiently diversified so that the local economy is not disrupted or destroyed.

Figure 3

Elements and Components of Resiliency in a River Basin

This chapter examines some possible measures to promote better floodplain management and community resilience, including floodplain definition, building standards, education, flood insurance, use of expertise, monitoring, and assistance. It concludes with a brief review of some research on the social ramifications of flooding and points to areas for further research.

Canada and the United States differ in their approach to flood preparedness and community resiliency. The United States has a framework for dealing with the issues through the National Flood Insurance Program (NFIP) and the National Mitigation Strategy. While an event like the 1997 flood reveals that this approach still has shortcomings and gaps, it does link flood insurance to mapping, building standards, community action, and financial incentives to adopt appropriate mitigation measures. The Canadian approach is less integrated. Canadian flood preparedness and community resiliency efforts deal with many of the same elements, but there is currently no common program or framework tying them together. Results tend to be event-driven, ad hoc, with little programming emphasis on individual responsibility for mitigation initiatives.

Definitions

FLOODPLAIN - Any land area susceptible to inundation by floodwaters from any source.

100-YEAR FLOOD - A flood having a one percent chance of being equalled or exceeded in magnitude in any given year—not a flood occurring once every 100 years.

100-YEAR FLOODPLAIN - The area adjoining a river, stream, or watercourse covered by water during a 100-year flood.

FLOODWAY - The channel of a river or watercourse, and adjacent areas. In the U.S., these areas must be reserved in order to discharge a 100-year flood without cumulatively increasing the water surface elevation more than one foot.

FLOOD FRINGE - That portion of the floodplain outside the floodway that is inundated by flood waters in which encroachment is permissible.

ENCROACHMENT - Any obstruction in the floodplain that hinders the natural passage of flood waters.

SURCHARGE - An increase in flood elevation due to obstruction of the floodplain that reduces its conveyance capacity.

Floodplain Management

For communities and residents to take responsibility for flood preparation, they need to understand where the water will flow in floods of various magnitudes and how often they will be at risk. Basic to this understanding is floodplain mapping. In general terms, the floodplain is that portion of a river basin covered by water during a flood. Regulatory measures, however, require a more precise standard. To administer the U.S. National Flood Insurance Program, the Federal Emergency Management Agency (FEMA) uses the 100-year flood—that is, a flood with a one percent chance of being equaled or exceeded in any given year. Manitoba uses the floodplain of the 1997 flood.

The choice of a particular flood—a 100-year rather than 150-, 250-, or 500-year flood—is arbitrary. People living just outside a 100-year designated floodplain are not significantly safer than those living within its precise boundaries.

The area demarcated by a particular standard should be redefined when new statistical, hydrological, hydraulic, or historical information yields more accurate maps. The Task Force and others have developed new data, tools, and techniques to improve floodplain definition in the Red River basin.

A well-informed public should have knowledge of three related flood risk areas:

- the floodway, where hazards are high and occupancy and use must be severely limited;
- the regulatory floodplain, where occupancy and use are allowed, provided certain floodplain management requirements are met; and
- the lower-risk floodplain, where regulations may not be required but certain occupancy and use considerations are recommended.

Floodway: In general, the floodway* is where flood water flows swifter or deeper and poses a threat to life and property—typically the river channel, tributary channels and major overland flow areas. Obstructions in the floodway should not significantly affect upstream properties; according to U.S. legislation, they should have zero impact. FEMA defines the regulatory floodway as the channel of a river or other watercourse and the adjacent land areas that must be reserved to discharge a 100-year flood without cumulatively increasing the water surface elevation more than one foot. Floodways in the U.S. portion of the Red River basin have been defined for urban areas. In Manitoba, the most flood-prone communities have ring dikes or are now constructing them. Neither country has identified floodways in rural areas or urban expansion areas. In general, floodways in the Red River basin should be hydraulically defined and building or encroachment on the floodway should be severely restricted.

Regulatory Floodplain: Structures in a regulatory floodplain are at risk of flooding, but generally from lesser water depths and lower velocities than would occur in a floodway where there might be a threat to life and risks to property. Elevated and floodproofed[23] structures in a regulatory floodplain are likely to survive a major flood. Parts of the floodplain are often evacuated during a flood. For regulatory purposes, standard practice in the U.S. portion of the basin defines a floodplain in terms of the one-percent, or 100-year flood.

The area of the defined floodplain may change with new information, especially following major floods, and with the development of new flood control structures, dikes, or other infrastructure. A systematic program to ensure application of new information to floodplain definition is essential. In the United States, FEMA is required within every five years to assess the need to revise and update all floodplain areas and flood risk zones identified under the NFIP.

In Manitoba, the Department of Conservation defines its designated flood area (DFA) as the 100-year flood or a specific event, whichever is greater. As the standard for regulations in other provincial departments is the 100-year flood, this inconsistency may lead to confusion. Analysis of the 1997 flood shows that it is a 1:90 year flood at Winnipeg but greater than a 100-year flood from Ste. Agathe to the international boundary.

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* *The use of the term floodway should not be confused with the Red River Floodway, which is a 47.3 kilometre (29 mile) channel constructed to divert Red River floodwaters around Winnipeg.*

Recommendation 13: ***In the U.S. portion of the Red River basin, the 100-year floodplain should continue to be defined in light of the best available information and the revised flood elevations should be used as the basis for floodplain regulations.***

Recommendation 14: ***In Manitoba, either the flood of record or the one-percent flood should be used for Red River basin regulations.***

U.S. Critical Facilities

Hazardous Materials Production, Storage and Waste Facilities

- Superfund sites
- Landfills
- Hazardous waste facilities
- Petrochemicals and major pipelines

Essential Utilities

- Municipal and industrial National Pollutant Discharge Elimination System sites
- Water treatment plants
- Major water supply intakes
- Water well field
- Sewage treatment plants
- Power plants
- Major power utility substation
- Communications equipment and related antennas

Essential Services

- Hospitals
- Group homes for the mobility impaired
- Schools
- Major Airports
- Post offices
- State or federal bridges
- Prisons

Emergency Services

- Fire Department
- Police stations
- Military bases
- Major computer centers

Lower Risk Floodplain: Areas outside the regulatory floodplain flood much less frequently. Despite less frequent flooding, hospitals, fire stations, police stations, water treatment plants and other critical facilities may still need to be protected where economically feasible and where essential in flooding emergencies. The United States federal government uses the 500-year standard of protection for any "critical action" using federal funds.[23] A "critical action" is an action for which even a slight risk of flooding is too great. The Red River spreads so much during major floods that, for the most part, large increases in flood volume raise water levels relatively little. Except immediately south of Winnipeg, the difference in elevation between a 100-year flood and a much larger, rarer flood is small. In certain circumstances, dikes to protect against larger floods may cost little more than for a 100-year flood. The 500-year floodplain is delineated (as B Zone) on the NFIP flood insurance rate maps (FIRMs).

Recommendation 15: ***The 500-year flood (0.2 percent flood) should be defined throughout the Red River basin and used to inform the public of the potential risks of flooding from rare events, including the need to buy flood insurance in the United States, and as the basis of regulations for siting and floodproofing critical facilities.***

In the United States, areas protected by levees meeting NFIP criteria are considered out of the 100-year floodplain. NFIP levee criteria include a three-foot freeboard requirement above the 100-year flood elevation. Protected areas for such levees are generally identified as an area of lesser risk (Zone B or Zone X on flood insurance rate maps). The river side of the levee is generally a floodway and is shown with cross hatching. Dikes, flood channels, and other measures to prevent damages against, for example, a 100-year flood, may only postpone damage until a larger flood occurs. The flood defenses enable more development than if the area had remained unprotected. As a consequence, property damage will be greater if the works fail in larger floods. Protection has limits, and people remain at risk—the risks are less but damages could be catastrophic. Consideration should be given to floodproofing behind dikes to protect against possible overtopping or a breach.

Building Standards

Much of the flood damage in 1997 was the result of the dominant housing style—one- or two-story homes on full basement foundations, with basements used as living space. Housing appropriate to the floodplain would foster long-term resilience. But what is appropriate? The NFIP prohibits construction of residential buildings with basements in the 100-year floodplain. All new or substantially improved buildings must have the lowest floor including basement elevated to or above the 100-year flood elevation. Dry floodproofing of residential buildings is prohibited. The lowest floor including basement of a commercial and non-residential buildings must be elevated or dry floodproofed to or above the 100-year flood elevation. However, NFIP community exception criteria allow floodproofed residential basements in certain areas. Exceptions are granted to communities likely to experience specific flood risks (water depths and velocities), if the community adopts specific design and construction requirements for floodproofed residential basements. Several communities in the basin have this FEMA exception.

Both Minnesota and North Dakota base their building codes on the Uniform Building Code, which will become part of a new U.S. national model code, the International Building Code. Minnesota includes floodproofing standards in its code while North Dakota does not. Cities and counties in both states may adopt the state building code and take responsibility for subsequent enforcement. Few jurisdictions in the Red River basin have adopted the state code.

Recommendation 16: ***Both North Dakota and Minnesota should consider adopting the new International Building Code that includes requirements for design and construction in flood hazard areas.***

Canada has a national model building code that provinces may adopt in whole or in part. However, there are no National Building Code requirements for structures on floodplains. The apparent justification is that people should not build on floodplains. Such a view is inappropriate for Manitoba, where approximately 70 percent of the people live on the floodplain. In the United States, FEMA has been working with the American Society of Civil Engineers on a national standard (ASCE 24) for building design in flood hazard areas.

Recommendation 17: ***The National Building Code of Canada should specify design and construction standards for buildings in flood hazard areas such as the Red River basin. Floodplain construction requirements should be incorporated into the Manitoba code when available.***

Education

Public awareness activities should emphasize the flood risk associated with any floodplain location or any location structurally protected from floods.

Flood protection standards and works can give a misleading sense of security. Many people seem to believe that the measures in place—standards, flood protection measures, and buildings constructed above the base flood elevation or outside the mapped special flood hazard area—give them adequate or even complete protection. Public awareness activities should emphasize the flood risk associated with any floodplain location or any location structurally protected from floods.

Flood protection standards protect against an identifiable degree of risk—for example, the 100-year flood. However, individuals and localities are still subject to residual flood risk. Nearly 25 percent of flood insurance claims in the United States are from outside the 100-year floodplain. Individuals and localities need to account for that residual risk by building communities resilient to flooding.

IFMI aims for a transboundary consensus on actions to improve disaster resilience.

In the United States, FEMA's Project Impact is a major initiative that encourages communities to protect themselves from the effects of natural disaster by taking action to reduce disruption and cost. The three principles of the initiative are: preventive actions at the local level; private sector participation; and long-term investment in prevention measures. In the Red River basin FEMA has initiated a pilot of a new concept for Project Impact, The International Flood Mitigation Initiative (IFMI). The initiative aims for a transboundary consensus on actions to improve disaster resilience. The Province of Manitoba is also contributing to IFMI. The effort has been characterized by a number of public meetings and working sessions involving a broad cross-section of individuals from both the public and private sectors.

Recommendation 18: *Federal, state, provincial, and local governments in the Red River Basin, in conjunction with the private sector, should continue to develop, refine, and implement effective strategies to improve the disaster resiliency in basin communities. Efforts should be made to increase public awareness of flood risks throughout the basin.*

Enforcement

Building codes, zoning and other regulatory measures are only as effective as their enforcement. Enforcement effectiveness usually mirrors resources, training, public understanding and commitment, and related political will. In some cases, one or all of these elements are lacking.

Recommendation 19: *State, provincial and other appropriate authorities should review the effectiveness of and compliance with the floodplain management regulations in the basin and take steps as needed to improve enforcement.*

Floodplain Acquisition

Buyouts of flood-damaged buildings reduce future flood losses and help build resilience but only if the vacated land remains permanently as open space. In the United States, programs and funding should continue for voluntary buyouts of structures subject to repetitive flood damage or at great flood risk. This policy is effective, and many observers advocate its expansion.

Current FEMA policy prohibits the construction of levees, floodwalls, and other flood control projects on land that was acquired as a result of the Hazard Mitigation Grant Program (HMGP) 25. FEMA is in the process of developing a Memorandum of Agreement with the U.S. Army Corps of Engineers that addresses the construction of flood control projects on this acquired land. Coordination and consultation procedures and the issue of limited exceptions to the above policy are being discussed in the development of this agreement. The FEMA-Corps discussions, however, do not deal with state and other non-federal projects, and should be expanded to include non-federal agencies and projects.

In East Grand Forks, Minnesota the existing emergency levee is located nearly at the top of the channel bank of the Red River. The proposed U.S. Army Corps of Engineers project for the city, if built, would relocate the levees up to 1000 feet (304 m) landward to the limits of the existing 100-year flood plain. Additionally, the area between the river bank and the new levee would be cleared of structures (approximately 700) and maintained as open space. The alignment of the setback levees may use some HMGP acquired lands. FEMA and the USACE are in the process of reviewing this particular project to determine the appropriate action in consideration of the FEMA policy on the use of HMGP acquired property.

Recommendation 20: *While the restriction of reuse of acquired properties is prudent as applied to residential, commercial or other non-flood damage mitigation purposes, FEMA should revise its interpretation of "structures" under the Hazard Mitigation Grant Program regulations to exempt water level control devices, dikes, levees, flood walls and any other feature that would mitigate future flood losses.*

Recommendation 21: *The Canadian federal government should include in the Disaster Financial Assistance Arrangements provisions to allow for the permanent removal of structures in areas subject to repeated flooding.*

F3

Mitigation Approach

Following a major flood, funding is often provided for actions that correct and mitigate the damage experienced. This time of crisis presents an opportunity in which community will and resources are available for worthwhile mitigation initiatives. However, after a major flood, governments must act quickly and there is little time to coordinate projects. To avoid piecemeal implementation and confusion, emergency and floodplain managers need to work out beforehand what should be done in the post-flood period. Action taken at one site, or for one purpose, should not hinder another. Basin or local mitigation plans that spell out the overall strategy are helpful. Mitigation activities need to be coordinated among funding entities, as well as among federal, state, provincial and local jurisdictions.

United States National Mitigation Strategy

The National Mitigation Strategy encompasses all U.S. state and federal agencies, as well as the emergency management community and the public. It has two components. By the year 2010, it aims to:

(1) substantially increase public awareness of natural hazard risk, so that the public will demand safer communities in which to live and work; and

(2) significantly reduce the risk of loss of life, injury, and economic, natural, and cultural resources that result from natural hazards.

The foundation of the Strategy involves strengthening partnerships and creating them where none exist in order to empower all Americans to fulfill their responsibility for building safer communities. These partnerships are essential to the five major elements of the Strategy:

1. Hazard identification and risk assessment;
2. Applied research and technology transfer;
3. Public awareness, training, and education;
4. Incentives and resources;
5. Leadership and coordination.

The Strategy sets forth a series of objectives by which to measure success in achieving the national mitigation goal and offers the basis for establishing priorities for the use of limited resources in fulfilling the major elements. Most important in this regard is the Mitigation Action Plan, or MAP, which highlights actions Americans and their governments must take to successfully launch the National Mitigation Strategy.

Recommendation 22: *FEMA and Emergency Preparedness Canada should develop an integrated approach to mitigation initiatives at all political levels based on a comprehensive mitigation strategy for the entire basin. In the United States, the strategy should be integrated within the National Mitigation Strategy.*

Despite implementation problems within the Red River basin, the United States has a national mitigation strategy (see box) and an approach for dealing with flood mitigation. Through the combined use of insurance, incentives, and land use and building standards, the National Flood Insurance Program promotes numerous mitigation initiatives. Canada has no strategy to guide or fund mitigation measures supported by the federal government or partnership with the provinces.

The Canadian approach emphasizes flood-fighting preparedness, response, and recovery. For example, the $130 million in federal and provincial funds available for flood protection and flood proofing supports the construction and raising of ring dikes around basin communities until 2002 and helps homeowners, farmers, and businesses finance the floodproofing of their establishments. As important as mitigation might be, however, there is no coordinated approach to integrate structural and non-structural mitigation measures.

That may change. Emergency Preparedness Canada, in cooperation with the Insurance Bureau of Canada's Institute for Catastrophic Loss Reduction, has proposed a National Mitigation Policy. Further consideration should be given to this proposal and to introducing a variety of mechanisms (such as funding programs and technical assistance) to support mitigation programs at the local level. The federal government should have policies that encourage the development and funding of mitigation strategies with provincial and local partners.

Recommendation 23: *The Canadian federal government should establish a national flood mitigation strategy, or a broader disaster mitigation strategy, and support it with comprehensive mitigation programs.*

In its proposal, *A National Mitigation Strategy*, the Insurance Bureau of Canada recommends:

- establishment of a natural disaster protection fund, into which governments invest $100 million to $150 million a year to reduce the costs of future suffering and disaster recovery;
- expansion of the governments' response and recovery program by 15 percent to invest in mechanisms to prevent the recurrence of extreme events; and
- the creation, by insurers, governments, and others, of a new organization to promote prevention, mitigation and preparedness.

Flood Insurance

Flood insurance can be a positive public force for promoting flood preparedness and resiliency. It helps individuals assume responsibility for living in flood-prone areas and permits government funds to be directed to mitigation and other measures more sustainable than recovery assistance. In the United States, communities and states play an important role. To participate in the National Flood Insurance Program, a community must agree to adopt and enforce floodplain management requirements. If these conditions have not been met, federally backed flood insurance cannot be purchased. All new and substantially improved construction is then actuarially rated.

In Canada, standard residential property insurance policies do not cover flood damage. The flood insurance issue requires examination. Because the subscription base is smaller than in the United States, conditions may differ in Canada. The 1,300 flood-prone

U.S. National Flood Insurance Program

The National Flood Insurance Program (NFIP), established by the National Flood Insurance Act of 1968, makes federally-backed flood insurance available in states and communities that agree to adopt and enforce floodplain management measures that meet or exceed minimum federal criteria. In 1973, the Act was broadened to require the purchase of flood insurance as a prerequisite for obtaining any form of federal or federally related financial assistance, such as mortgage loans from federally-insured lending institutions. More than 18,400 communities now participate in the program, and the NFIP has mapped floodplains in over 20,000 communities. The 1994 National Flood Insurance Reform Act strengthened the NFIP by providing for mitigation insurance and establishing a grant program for state and community flood mitigation planning and projects.

The 1968 Act also requires the President to develop a Unified National Program for Floodplain Management. A 1994 update includes a set of national goals for floodplain management. Executive Order 11988 (Guidelines for Floodplain Management), issued in 1977, requires federal agencies to undertake a planning process prior to taking actions that affect floodplains. The Midwest floods of 1993 resulted in a further evolution in federal flood policy. Now there is a new emphasis on the acquisition or relocation of flood-damaged properties using funding from a number of federal programs and from state and local governments and the private sector. These floods also led to a reexamination of federal floodplain management policies and programs by the Administration.

communities in the country are concentrated mostly in the Great Lakes–St. Lawrence Basin, whereas the estimated 19,000 flood-prone communities in the United States are dispersed more widely. Since the end of Canada's federal-provincial Flood Damage Reduction Program in 1993, there has also been a lack of current floodplain information and the means to produce it. However, options could be examined to determine if a viable flood insurance program—one that learns from the United States experience—is possible in Canada.

In the United States, purchase and renewal rates are low where property owners are not required to have flood insurance. The purchase rates are much higher within the 100-year regulatory floodplain, where the National Flood Insurance Reform Act of 1994 requires property owners to purchase flood insurance before they may obtain loans involving federal funding or federally insured mortgages. Lending institutions face a financial penalty if they fail to require the purchase of such insurance. Many of the homes flooded in the Red River basin in 1997 were outside the 100-year floodplain and therefore were not required to have insurance.

In a sample of homeowners in Grand Forks, 94 percent knew about flood insurance, but only 20 percent had it at the time of the flood. Of those who did not have insurance, about 40 percent had inquired about flood insurance but had decided not to purchase it. Those who did not purchase insurance said they believed the National Weather Service crest predictions; they thought the dikes and flood control devices would provide adequate protection, or they thought that a flood would not damage their home.[26]

The incentive to participate in the NFIP is weakened if, during an emergency, compensation is given irrespective of insurance coverage.

Disincentives that discourage people from buying or renewing flood insurance policies in the Red River basin should be re-examined. For example, the short qualification period of 30 days before insurance comes into effect enables residents to predict the spring flood risk and to purchase only when the risk is high. Furthermore, after large floods, such as the one that occurred in 1997, the President may declare an emergency and make compensation available to insured and uninsured alike. The incentive to participate in the NFIP is weakened if, during an emergency, compensation is given irrespective of insurance coverage.

It should be noted that flood insurance can help residents recover from floods that are not declared emergencies, and that disaster assistance funds alone do not fully cover losses. Disaster assistance comes in the form of either an Individual Family Grant, with a maximum benefit of $13,000, or a low interest Small Business Administration loan, which must be repaid. There are no guarantees that properties will be bought out. Funding for a buyout project is initiated at the local level and requires state or local matching funds.

Within the NFIP, an incentive for good floodplain management is provided through the Community Rating System. The better a community's floodplain management, the more favorable the individual's NFIP insurance premiums. In addition, FEMA is currently working to close some of the gaps between its disaster assistance and flood insurance programs.

More emphasis needs to be placed on developing mechanisms to increase the participation and retention rate for the program and for FEMA to make the whole program actuarially sound.

> **Recommendation 24:** ***In the U. S. portion of the Red River basin, FEMA should expand current efforts to market the sale and retention of flood insurance both within and outside the 100-year floodplain. Innovative marketing should be considered to attract and retain policy holders, including increasing the waiting period from 30 days to 60 days before flood insurance comes into effect.***

Expertise and Information Sharing

Information about recovery and rebuilding techniques specific to the Red River basin should be shared between the United States and Canada as a matter of routine. One vehicle for doing this would be the formation of technical assistance teams comprising experts on clean-up techniques, molds, the draining and reconstruction of basements, and the design and building of ring dikes. These teams could serve as consultants to localities, give workshops for homeowners, and perform other similar services after a flood. A useful mechanism being developed by the Task Force and the Global Disaster Information Network is a basin-wide database of technical and other information related to recovery, mitigation, and flood resilience, accompanied by lists of sources of additional information. This database could be made widely accessible through public libraries or the Internet.

> **Recommendation 25:** ***Recovery, rebuilding, and mitigation expertise and information should be widely shared across the border in advance of flooding.***

Resilience Monitoring

Snow cover, water levels, soil moisture, and other indicators of potential flood risk are routinely measured in the basin, but indices of resilience, such as the extent of occupancy of the floodplain, number of insured households, sales tax revenues, and health of riparian ecosystems, are not. This lack of information handicaps efforts to build flood-resilient communities. Monitoring such factors would not only help identify problems and deficiencies in individual and community resilience, but it would also help establish a baseline against which progress can be measured. Resilience is not static, and monitoring would need to be done routinely to capture the ebbs and flows in the basin's status.

Recommendation 26: ***Measures of flood resilience should be developed, and a system should be established to monitor resilience in the Red River basin.***

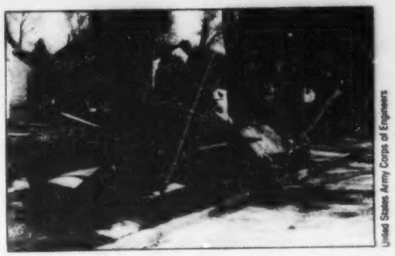
The Human Effects of Flooding

The 1997 flood has inspired considerable research that can lead to the reduction of the human effects of flooding and to increased flood resiliency of the population.

The effects of flooding on the human population is an indicator of resiliency. While the Task Force was unable to examine these issues in depth, it recognizes that the 1997 flood has inspired considerable research that can lead to the reduction of the human effects of flooding and to increased flood resiliency of the population. The Task Force commissioned a review of the available research[27] from which the following preliminary findings are drawn:

- The widespread disruption of households after the flood may have affected women more than men. Women tended to shoulder more of the responsibility for domestic arrangements and duties, and these were made much more difficult when undertaken in temporary, often unsuitable, housing arrangements.
- Women with home-based businesses, especially day care, suffered from the disruption of those businesses as well as of their homes, first by the evacuation and then by the flood damage to housing.
- In the early months after the flood, businesses owned or managed by women in Grand Forks were twice as likely to remain closed as were others.
- Women in the United States were at increased risk of domestic violence after the flood; protection orders increased significantly, as did counseling calls to crisis centers. The Grand Forks shelter closed, leaving a gap in safe housing. Shelters were closed or relocated, and some women were forced by the flood to re-establish contact with or even return to violent partners.
- Stereotypical gender patterns became more prominent after the flood, to the detriment of women. Women's domestic and kin work intensified when living conditions were disrupted, but both men and women tended to discount women's extra behind-the-scenes work before, during, and after evacuation.

- Most women interviewed in Grand Forks reported a sense of accomplishment, confidence, and competence as a result of having had to assume multiple roles (additional domestic duties because of flood and the related evacuation; a paid job or profession; or volunteer relief, emergency response, or other activities).
- The stress to residents in the flooded and evacuated areas of Manitoba was increased by their inability to access timely, relevant flood-warning, evacuation, and recovery information from governments.



United States Army Corps of Engineers

- The flood tested marital relationships. Among Greater Grand Forks couples, for example, marriages that were strong before the flood emerged stronger in its aftermath; weak pre-flood relationships were further weakened. The relationships of couples with moderate levels of flood damage fared somewhat more poorly than the relationships of couples with little damage or total damage.
- Domestic violence in Grand Forks increased after the flood. People with lower social support, the elderly, and those with a prior history of violence were most affected.
- The flood seriously hindered domestic violence programs in the Red River Valley. As much as one year afterward, programs reported increased demands for service but fewer organizational resources (personnel, facilities, and money) than before the flood. In addition, the programs were largely unprepared to protect battered women and their children during and immediately after the flood, when housing was disrupted.
- Racial and cultural bias was evident in some aspects of recovery in the United States. Migrant families lost access to low-cost housing and other supplies, but were offered little recovery assistance. Some Hispanic women reported that volunteers in some relief projects effectively restricted aid to non-Hispanic residents.
- A majority (65 percent) of social practitioners dealing with juveniles, the family, mental health, and gerontology in Greater Grand Forks said that their clients were unsettled by the flood. Those with the fewest economic and personal resources beforehand were most upset. Financial and housing problems caused clients more anxiety and depression, and increases were reported in family violence and alcohol abuse, and in acting out by youths.

- Clients of social service agencies in Grand Forks generally reported receiving more and better attention after the flood from individual professionals and organizations. They noted the expanded efforts of some entities (such as the Salvation Army, churches, and church groups) and the appearance of new sources of assistance (such as the Federal Emergency Management Agency and the Red Cross).

More research is needed before the immediate and long-term social effects of the Red River flood can be fully understood.

Many issues have not yet been studied, and more research is needed before the immediate and long-term social effects of the Red River flood can be fully understood. Some of the areas where research may be helpful include the general area of basin-wide flood resilience, effects of temporary or permanent relocation, effects of the flood on quality of life, effects on children and minorities, implications for community and social identity, effect on farmers and farming communities, schools and the educational system, housing and other structure types that fared well or poorly in the flood, market and non-market losses, and positive results of the flooding.

It would be useful, and relatively simple, to conduct follow-up studies on some of the findings already identified. For example, a certain number of years after the flood, how many people carry flood insurance? For what reasons? Have the reasons changed from those reported by Pynn and Ljung?[28]

7

Flooding in the Lower Pembina River Basin

Unilateral dike building has been the source of transboundary disputes and tension in the Pembina Basin for more than 50 years.

Flooding on the lower Pembina River has led to uncoordinated unilateral flood protection efforts that have caused harm to residents on both sides of the border. Unilateral dike and road building has been the source of transboundary disputes and tension in the Pembina Basin for more than 50 years. Federal, state, provincial, and local governments have carried out a number of efforts and studies to find solutions to the problems of transboundary flood management, but none have succeeded. Following the 1997 flood, residents of the basin resolved to renew efforts to find solutions to the problems. They have asked the International Joint Commission to aid in this effort.

The Commission and the Task Force see an opportunity to help resolve the problems by working to develop a common understanding of the physical facts of the situation. The Task Force has undertaken detailed mapping of the lower basin and has created a computer model that can be used in consultation with local groups, to test alternative ideas about flooding and flood protection. The Task Force also initiated development of Internet-based information and analytical links to facilitate transboundary cooperation and issue resolution. Agreement has not yet been reached on specific actions to ameliorate transboundary damages, but some of the critical information and analytical tools are now in place.

Pembina Basin

The Pembina River basin straddles the United States–Canada boundary for 130 miles from the Turtle Mountain near Boissevain, Manitoba, to the Red River at Pembina, North Dakota. The watershed is about 3,950 square miles in area (10,230 km^2), divided nearly equally between Manitoba and North Dakota. The river flows in a generally easterly direction through Manitoba before turning southeast, crossing the international boundary about 15 miles (24 km) northwest of Walhalla, North Dakota, between the communities of Maida, North Dakota, and Kaleida, Manitoba. From there the river continues on its way through North Dakota to the Red River.

The current population of the basin is approximately 65,000, with about 40,000 in Manitoba and 25,000 in North Dakota. Agriculture and associated processing and service industries dominate the economy of the basin.

The Pembina Escarpment separates the watershed. The area west of the escarpment is an undulating glacial moraine upland of potholes, ridges, and knolls. In this area the Pembina River flows through a deep, incised valley. The entire Manitoba portion of the Pembina River watershed lies above the Pembina Escarpment.

Near Walhalla, the river emerges from the uplands and flows onto the broad flat plain of the Red River Valley. Relief along the escarpment in the Walhalla area drops abruptly from an elevation of approximately 1,500 feet above sea level (457 m) by 500 to 600 feet (152 to 183 m) to the plain below. Over the next 15 miles (24 km) downstream from the escarpment, the valley containing the Pembina gradually disappears. From a point near Leroy, North Dakota, through the town of Neche and on to its confluence with the Red River at the city of Pembina—a distance of approximately 20 miles (32 km)—the river is at the same level as the surrounding plain, or slightly higher, confined by natural levees built up over centuries of flooding, or by man-made levees constructed in an attempt to control flooding.[29]

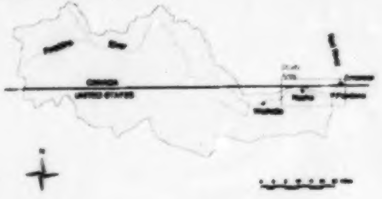
The Problem

Spring floods are a natural and common occurrence along the entire length of the Pembina River. But the most significant and devastating flooding occurs along the 35-mile (56.4 km) reach between the Pembina Escarpment at Walhalla and the Red River.

Since the river in the vicinity of Neche is at, or slightly above, the elevation of the land around it, flood flows breaking out of the main stem of the Pembina River under natural conditions move away from the river and overland into the Tongue River watershed to the south, or north toward Canada and eastward to the Red. The natural levees along the river impede the return of floodwater to the channel, and it does not return unless forced to do so by impediments such as roads.[30]

Figure 4

Pembina River Basin



Historical accounts mention major floods in 1882, 1897, 1904, and 1916. Since 1940, several other significant floods have occurred on the Pembina River downstream of the escarpment, including those of 1950, 1974, 1979, 1996, and 1997. Until the flood of the century in 1997 (at 14,300 cfs or 405 cms), the 1950 flood was the largest on record, at 10,700 cfs (303 cms). Based on statistical analysis of the flood peaks, the 100-year flood is deemed to be 18,000 cfs (510 cms).

Table 10

Major Floods on the Pembina Since 1950

Date	Peak Flow at Neche
Apr 27, 1997	14,300 cfs*
Apr 20, 1950	10,700
Apr 28, 1974	10,300
Apr 20, 1970	9,600
Apr 20, 1979	9,500
Apr 23, 1995	8,500
Apr 16, 1998	7,620
Apr 18, 1996	7,500
Apr 21, 1969	7,360
Apr 12, 1971	7,350
Apr 27, 1970	7,070

Note: Channel capacity at Neche is approximately 6,000 cfs.
* 1 cubic foot per second is equivalent to 0.0283 cubic metres per second

A Historical Perspective

For more than 50 years, efforts to solve the problem of flooding along the Pembina River have ranged from local, unilateral efforts to a number of attempts at international cooperation in fighting a common problem. In many cases, groups of local people have taken the matter into their own hands. These unilateral actions on both sides of the border have created tension between landowners and governments on either side.

As early as the 1940s, there were reports of Manitoba farmers and municipalities building a road-dike along the international boundary, creating an obstruction to cross-border flows. While there were culverts through the road-dike, they were not large or numerous enough to handle more than a minimum flow. When North Dakota farmers in Pembina County suffered damage and crop production losses in 1944 as a result of overland flooding, they reasoned that the blockage to the movement of the floodwaters into Canada had been the cause.

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For their part, Canadian farmers expressed concern over a large land drainage project being planned in North Dakota. They asked for a complete survey of the proposed project and an accurate estimate of additional waters to be drained into Manitoba.

Following the 1950 flood, American farmers in the Neche area began to build dikes along the river to protect their land. After each major flood (in 1966 and 1969, for example) these dikes were extended or raised in preparation for the next flood. The Canadian action along the boundary in the 1950s and 1960s responded to increased overland flows from the south, which Canadians believed was aggravated in large part by the construction of these levees.

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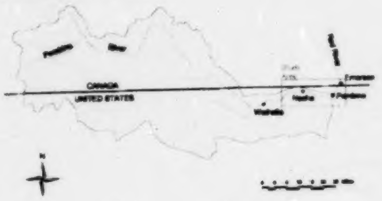

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In an attempt to manage runoff reaching the [illegible] boundary from several drainage channels in North Dakota, Manitoba and North Dakota reached a tentative agreement in 1956 to construct the Rhineland Drain, also known as the International Boundary Drain. The drain runs parallel to the international boundary, just inside the Canadian border from a point about one mile (1.6 km) west of Gretna, Manitoba to the Aux Marais River crossing—a distance of about eight miles (12.9 km). The Aux Marais watershed extends a short distance into North Dakota in the area east of Gretna, Manitoba. From there it flows northeast through Manitoba to join the Red River near Letellier.

For three years after the drain was completed in the spring of 1959, negotiations continued over the installation of culverts and field inlets into the drain. In 1964, concerned over the possibility of additional flooding south of the border, the North Dakota State Water Commission and the county boards expressed an interest in extending the Rhineland Drain eastward along the boundary to the Red River. The proposal, however, was not feasible because of the depth of cuts required through the terrain. An alternative approach sought to redirect water eastward to the Red River using natural channels as much as possible. This option also floundered when the North Dakota State Highway Department indicated it had no obligation to construct or maintain a structure to accommodate the drain through Interstate 29. Local interests on the downstream end of the proposed project also expressed strong opposition to the project, and it was abandoned.

In October 1968, North Dakota expressed a further interest in improving drainage in the United States, with the hope of increasing the Aux Marais channel capacity to help accommodate additional flows. Manitoba expressed a willingness to increase the capacity of the Aux Marais River, but only if it could manage the amount of floodwater runoff entering Manitoba from North Dakota.

During the 1970s, the border issue began to intensify.

The 1970s were a decade of significant floods, in 1970, 1971, 1974, and 1979. During this period, the border issue began to intensify. Believing that construction activities along the international boundary violated the 1909 Boundary Waters Treaty, North Dakotans asked the International Joint Commission to review the problem. The IJC suggested that the problem should be referred to the Souris–Red River Engineering Board. In March 1970, the Governor of North Dakota asked the U.S. Secretary of State to involve the IJC.

On May 4, 1970, the U.S. State Department requested that the Canadians "secure the removal or reconstruction of the (boundary levee) in order that the normal flow of flood waters across the boundary may be restored," in compliance with the 1909 Treaty.

During the April 1971 flood, there were unsubstantiated reports that Canadian farmers were patrolling their road-dike to prevent sabotage. Once again, the Governor of North Dakota asked the IJC to take action to relieve the problem. The IJC replied that it had no authority to prevent or halt any violation of the Boundary Waters Treaty without a request from governments.

Following each major flood in the 1970s, diking activities flourished on both sides of the border.

Following each major flood in the 1970s, diking activities flourished on both sides of the border. The dikes along the Pembina River in North Dakota were extended and raised. Canadian farmers continued to extend and raise the road-dike along the international boundary. As the road system in the area was developed and improved over the years, roads also became a significant factor in altering natural overland flows.

Between 1979 and 1990, an extended period of low flows and drought conditions helped ease the controversy surrounding water issues. However, the Red River valley was hit with another major flood in the spring of 1996, which breached the road-dike. North Dakota protested the efforts by local Manitobans to repair the breach, and the Manitoba government ordered that the repairs cease.

The 1997 flood is the largest on record for the lower Pembina River.

In April and May of 1997, record flooding occurred on the Pembina and Red rivers.

The 1997 Flood

The 1997 flood is the largest on record for the lower Pembina River. The Pembina [illegible] a double peak, a common, if not normal, occurrence. On April 22, a flow of [illegible] cfs (362 cms) was recorded at Neche as runoff from the lower portion of the basin passed. After dropping to 10,000 cfs (283 cms), the peak rose again three days later, this time to the record 14,300 cfs (405 cms), fed by runoff from upstream reaches of the river.

What was unusual (in addition to the size of the flood) was that the peaks on the Pembina and the Red coincided at their confluence. The peak runoff from local streams such as the Pembina is normally over by the time the peak on the Red River reaches the international boundary. The flows on the Red were in the order of ten times that of the Pembina. As a result, for a short distance from where it joins the Red River, the Pembina reversed its flow until it joined the overland flow from the Red and moved northward west of Interstate 29 and across the international boundary and into Manitoba.

Above Neche, most of the flow was contained within the river channel and associated levees, and by portions of the road network that acted as dikes in the area. Below Neche, the river broke out of its banks and moved south and north. To the south, County Road 55 contained the flow and redirected the flood waters back toward the river further downstream. From there, the flows continued overland until they met with overland flows from the rampaging Red River.

To the north, floodwater moved overland until it met the road-dike at the international boundary. Floodwater accumulated there until it spilled over a small height of land, known locally as Switzer Ridge, and then moved east to meet up with overland flows from the Red.

The eastern portion of the road-dike, just west of the Red River, was overtopped and failed in two locations. The failure, however, was more likely the result of combined overland flooding from the Red River and the Pembina, rather than of the Pembina itself. Following the flood, Canadians repaired the road-dike.

Along the international boundary from the Walhalla area to the Aux Marais River, six significant drainage ways cross into Manitoba from North Dakota.

Reservoir and Floodway Proposals

Along the international boundary from the Walhalla area to the Aux Marais River, six significant drainage ways cross into Manitoba from North Dakota. These are referred to by number; Crossing 1 is where Hyde Park coulee enters Manitoba, and Crossing 6 is the Aux Marais itself.

By 1973, discussions relating to the amount of water that should be allowed to pass into Canada along these drainage ways, and in particular through the Aux Marais, had been under way for nearly 20 years. That year, the Ad Hoc Canada–United States Water Resources Committee released a report containing a number of recommendations, among which were suggestions for installing additional culverts on the Aux Marais at the international boundary and at the five border crossings on the Walhalla–South Buffalo Lake watersheds. The committee also recommended that Aux Marais River and the Walhalla–South Branch of the Buffalo Lake System should be improved to accommodate flows equaled or exceeded once in eight years.

In addition, the committee developed a method of sharing the costs of the improvements and maintenance between Canada and the United States, based on the contributing drainage area for each channel lying within each country.

In October 1974, the Canada–United States Flood Control Review Committee was established to re-examine the recommendations and conclusions of the Ad Hoc Committee. In its terms of reference, the committee was instructed to assume, when preparing its recommendations regarding flow design or standard for drainage works, that the Pembilier Dam would be built, and to exclude from their consideration the presence of overflows from the Pembina River.

In its 1976 report, the Review Committee generally concurred with the earlier committee's recommendations. Only the recommendations describing the amount of flow crossing the border were revised, with more specific numbers and sizes of culverts to be installed.

In an inspection of the area in the spring of 1991, a technical committee of North Dakota officials and Manitoba Water Resources representatives determined that, in general, the actions recommended by the 1976 report (primarily in regard to the sizing and number of openings across the border) had not been applied. Manitoba, however, was in the process of upgrading the Aux Marais channel as recommended.

In 1996, a new International Technical Working Group examined the progress being made on the 1976 recommendations. The group determined that the Aux Marais system had been completed as recommended, with the exception of the emergency spillway. They also reached the consensus that waters reaching Crossings 1 to 5 further west were not affected by overflow from the Pembina, since they form part of the Walhalla–South Branch of the Buffalo Lake drainage systems. Accordingly, the Working Group agreed that the recommended openings in these border crossings could be installed, providing the cost-sharing agreement outlined in the 1976 report could be implemented.

The major stumbling block to a total solution seemed to be the failure to implement a flood control project on the Pembina River.

The major stumbling block to a total solution seemed to be the failure to implement a flood control project on the Pembina River. Canadian representatives insisted that no further changes should be made to the Aux Marais Crossing until provisions were made to handle additional flows from the Pembina River.

Nevertheless, the Pembilier Dam could still not be economically justified. The Working Group then considered the possibility of establishing an overflow channel, smaller than the one recommended earlier by the Corps, from the Aux Marais Crossing eastward about five miles (8 km) to join a natural channel to the Red River. The diversion would intercept excess flows on the Rhineland Drain at the Aux Marais Crossing and divert them along the south side of the border to the Red River. It was unclear whether local landowners and politicians would accept this proposal, and it has gone no further.

Early Studies

Prior to 1960, several studies were undertaken unilaterally in each country for the purpose of water management in the lower Pembina River basin. These studies revealed that no potential multi-purpose water management project could be justified economically unless both countries participated in the project.

In 1967 … the Commission recommended construction of two reservoirs to provide flood control, irrigation, and water supply to both the Manitoba and North Dakota portions of the Lower Pembina Basin.

In 1962, the governments of Canada and the United States requested the International Joint Commission to investigate and report on measures to develop the water resources of the Pembina River basin. In 1967, after considering recommendations made to it by the International Pembina River Engineering Board, the Commission recommended construction of two reservoirs to provide flood control, irrigation, and water supply to both the Manitoba and North Dakota portions of the Lower Pembina Basin.[31] The Pembilier Dam would be located immediately upstream of Walhalla and would provide 110,000 acre-feet of flood storage. The Pembina Dam would be constructed near Kaleida, Manitoba, and would be used entirely for irrigation and water supply.

In 1976, the Corps recommended the construction of a larger version of the Pembilier Dam.

Since implementation of the 1967 IJC proposal was being delayed, the U.S. Army Corps of Engineers initiated a study to examine the possibility of providing flood control and water supply by constructing a project within the U.S. portion of the basin alone.

In its 1976 report,[32] the Corps recommended the construction of a larger version of the Pembilier Dam than had been suggested in earlier studies. Of the total 147,000 acre-feet storage capacity, the reservoir would use 128,000 acre-feet exclusively for flood control. The report also said that the project would "relax social pressures surrounding the existing diking problems along the international border. These dikes were constructed to reduce the flow of Pembina River floodwaters to the Aux Marais basin in Manitoba."

During its further investigations in the late 1970s and early 1980s, the Corps also examined the feasibility of constructing a floodway to provide a certain degree of flood protection to the area downstream of Walhalla. One option—a 3,500 cfs (99 cms) diversion from three miles (4.8 km) east of Walhalla, north to the international boundary then east to the Red—was considered to be economically feasible and would provide a significant level of flood relief. However, it was not acceptable to the local people for a variety of reasons and, in the end, the report chose the Pembilier Dam and Reservoir as the most acceptable approach to flood control for the area. The study resulted in a Congressional authorization for a Phase 1 study to further investigate feasibility of the Pembilier Dam. The project was feasible at the time of authorization, but subsequent Phase 1 studies found the reservoir not feasible, primarily because of the decline in agricultural crop prices.

In the late 1970s and early 1980s, the Corps examined the feasibility of constructing a floodway.

Following a major flood in 1979, the interest in flood control in the valley grew stronger. In 1983, the Corps revisited its 1976 findings. The drainage area contributing to the project and the probable maximum flood were larger than calculated in 1976. Costs were higher and benefits lower. The study also examined a number of other flood control options and finally selected a 21-mile (33.8 km) long floodway from a point six miles (9.7 km) west of Neche to the Red River as the most feasible plan. It had a positive benefit/cost ratio. This new proposal suggested locating the diversion point immediately upstream of Neche with a capacity of 2,000 cfs (57 cms).

Local objections to the plan were similar to those expressed in 1976. These included the loss of farmland to the channel, the relatively low level of flood protection being provided, inconvenience to farmers with land on either side of the channel, and the lack of water supply and recreational opportunities. Out of the 31 official responses received on the report, only eight supported the floodway plan and 19 supported the construction of the Pembilier Dam as the only acceptable solution to flooding in the area.

Under a 1980 Canada–Manitoba agreement for economic expansion and drought-proofing, the Prairie Farm Rehabilitation Administration (PFRA) conducted an extensive examination of options for supplying water to the area between the Pembina Escarpment and the Red River in Manitoba, an area referred to as the Assiniboine South–Hespeler Area. As part of the study, the feasibility of a dam on the Pembina River near Kaleida was considered. The relatively high cost of the project was a major drawback, and the Pembina Dam option was not pursued further by PFRA.

The most recent evaluation of reservoir construction on the Pembina for water supply and flood protection was conducted in 1999. The Lower Red River Valley Water Commission (Manitoba) contracted an engineering consulting firm, Acres International, to re-examine "sustainable water supply development and impacts of such development on flooding in the Red River basin." The Task Force provided half of the project funding.

Acres re-examined three projects discussed in previous reports—the Pembilier Dam and Reservoir, Pembina Dam combined with the Boundary Floodway, and the smaller Pembilier Dam and Floodway. A report indicating that costs exceed benefits has been prepared.

Current Activities

The Task Force believes that a solution to Pembina flooding issues requires—first of all —a common understanding of the facts of the situation. Technical information can help local groups and governments working to reach agreement on remedies to the transboundary flooding issues. The Task Force initiated a number of technical studies to aid in this effort. The work centered on three main initiatives—data acquisition and interpretation, model development, and decision support.

Technical information can help local groups and governments working to reach agreement on remedies to the transboundary flooding issues.

Data Acquisition and Interpretation. Accurate topographic data forms the basis for floodplain definition and floodplain management. To improve this information for the Red River Valley, the Task Force used a portion of the Lower Pembina basin to serve as a test area for preparation of a "seamless best available" Digital Elevation Model (DEM).

Three separate technologies were used to collect topographic data with the intent of fusing the data into one DEM. These were DGPS (differential global positioning system), Lidar (Light Detection And Ranging), and another, more experimental airborne technology, IFSAR (Inferometric Synthetic Aperture Radar). The U.S. Army Topographic Engineering Center managed the project.

In the fall of 1998, a DGPS survey of the centerline of paved and gravel roads and main levees was carried out. The data collected was processed to provide a complete set of elevations of these features to an accuracy of 2 to 4 inches (5 to 10 cm).

A 50,000-acre (20,234 hectare) section of the study area along the Pembina River from Neche to the Red River was flown in October 1998 using Lidar technology to acquire elevation readings accurate to 6 inches (15 cm). The data can be processed to produce a highly accurate "bare earth" DEM—that is, with buildings and trees removed in the processing.

IFSAR was also used to map the study area in October 1998. The aim of the system is to collect data for processing into a DEM at the rate of 40 square miles (104 km^2) a minute with 10-foot (3.05 m) vertical accuracy. By fusing the DGPS, Lidar, and IFSAR data, a more accurate IFSAR result may be possible. This analysis is still under way.

RADARSAT images of the study area were acquired for 12 days during the 1997 flood and four days during the 1996 flood. To assist future floodplain management and calibration of models, four RADARSAT images of the lower Pembina basin were produced. These images are coded for input into a GIS and the water features are classified. The satellite can obtain images in any weather, day or night, to a horizontal resolution of about 80 feet (24.4 m). The additional unprocessed data could be coded and classified as the need arises.

The U.S. Army Corps of Engineers recently analyzed flood frequencies for the Pembina River and found that there has been no significant change in the 100-year flood and the probable maximum flood as a result of the 1997 data.[33]

Model Development. The hydraulic models at the time of the 1997 Red River flood could not handle complex overland flows typical of a major flood in the valley. The Task Force sought a computer model capable of defining overland flows during a flood as well as one capable of being used for planning to determine the effects of new dikes or reservoirs.

The Task Force commissioned the development of two one-dimensional unsteady flow models aimed at achieving a water level accuracy of 6 inches (15 cm). A UNET model was implemented in the upper basin from Lake Traverse to Letellier, Manitoba, and a MIKE 11 model was applied to the lower basin from Grand Forks to Selkirk. The lower Pembina River basin is in the overlapping portion of the two models.

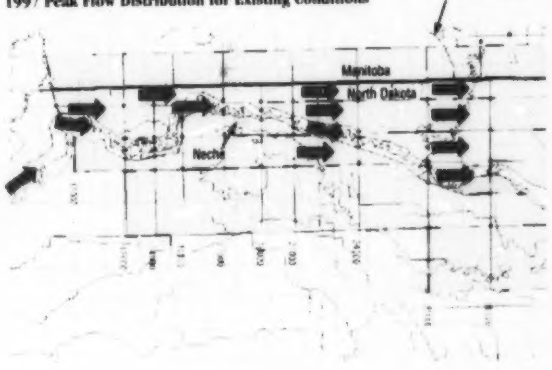
Storage (on the Pembina) was found to have no effect on water levels on the Red River at Emerson under 1997 conditions.

The models examined the effects of hypothetical upstream storage on lower basin water levels. Among the scenarios tested was the effect of storing 75,000 acre-feet of water at the optimum time in the Pembina basin. This storage was found to have no effect on water levels on the Red River at Emerson under 1997 conditions.

The Task Force added a detailed sub-model of the lower Pembina basin to the MIKE 11 model, which allowed examination of a variety of scenarios. The model was run for the Lower Pembina River for both 1996 and 1997 from a location about six miles (9.7 km) west of Neche to the confluence with the Red River at Pembina. A comprehensive discussion of the results of the modeling is presented in a separate report to the Task Force.[34] Findings can be summarized as follows:

Figure 5

1997 Peak Flow Distribution for Existing Conditions

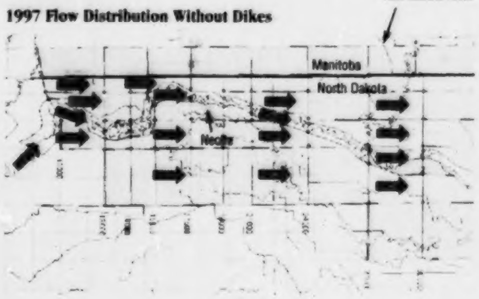


Under 1997 conditions, the flow on the Pembina River at Neche was 14,300 cfs (405 cms). This flow was contained within the channel, its associated dikes, and the adjacent road network until it broke out of the channel just east of Neche. About 15 percent of the flow (2,100 cfs or 59.5 m) moved northeastward from the breakout point to the international border, where it was impeded by the road-dike and by Switzer Ridge. A relatively small amount of the water passed through culverts in the road-dike and into the Aux Marais River. Most of the flow eventually crossed Switzer Ridge and continued along the U.S. side of the border and on to the Red River.

About 40 percent (5,700 cfs or 161 cms) moved away from the river to the south and east. This overland flow was confined by County Road 55 and forced to the east and eventually back across the river to the north side where it continued overland to the Red River. In effect, the road-dike along the international border on the north and county road 55 on the south acted as setback dikes, containing the flow between them.

Figure 6

1997 Flow Distribution Without Dikes



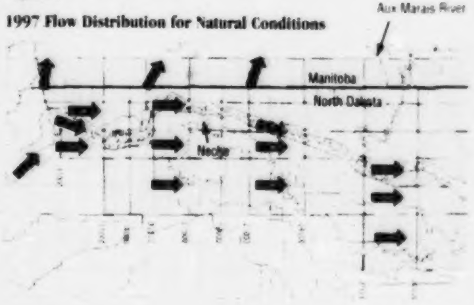
The modeling has shown that the capacity of the Pembina River channel downstream of Neche, with the existing dikes, is in the range of 5,100 to 6,400 cfs (144 to 181 cms).

Removing the system of dikes along the Lower Pembina River shows an entirely different overland flow pattern.. With no manmade levees in place, and under 1997 flows of 14,300 cfs (405 cms), the simulation revealed that the flow would have broken out of the channel west of Neche, instead of east. In addition, existing roads on the north side of the river would act as dikes locally and prevent Pembina River flows from reaching the international boundary. About 40 percent of the flow (5,700 cfs or 161 cms) would remain in the channel and the remaining amount would spill out on the south side of the river, flowing south and east, eventually meeting up with the river downstream and crossing it on its way overland to the Red. Again, County Road 55 acts as a setback dike on the south side of the river.

Under natural conditions—with no dikes along the river and no roads in place—flood flows would have left the river channel west of Neche. About 30 percent of the flow (4,300 cfs or 122 cms) would find its way north, 15 percent into the South Buffalo Drain in Manitoba via Hyde Park Coulee in North Dakota and another 15 percent further east. However, no floodwaters would flow along the international boundary east of Neche and no flow would enter the Aux Marais system.

Figure 7

1997 Flow Distribution for Natural Conditions



An additional 30 percent of the flow would escape to the south, past the present location of County Road 55. Only 30 to 40 percent of the total flow (4,300 to 5,700 cfs or 122 to 161 cms) would remain in the channel through Neche. This should be considered the natural capacity of the Lower Pembina River.

An engineered floodway of 2,000 cfs (56.6 cms) along the international boundary, as proposed by the U.S. Army Corps of Engineers in 1983, would have a minimal impact on flooding under conditions similar to those that occurred in 1997. The floodway would, however, provide benefits in lower flood years such as 1996.

Figure 8

1997 Flow Distribution with Boundary Floodway

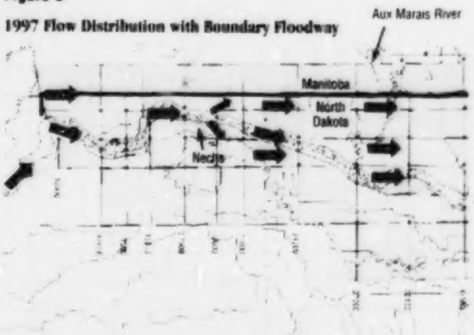
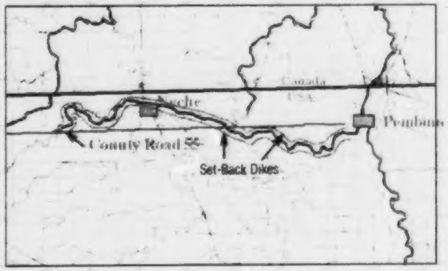


Figure 9

Set-Back Dikes



The model examined the feasibility of building a system of dikes set back from the river from a location upstream of Neche eastward to the Red River. The dikes would be set 2,700 feet (823 m) apart. Removing trees and shrubs from the channel between the dikes would increase its hydraulic efficiency but may not be environmentally acceptable. Allowing the natural vegetation to remain in the channel would decrease its hydraulic efficiency and require that the dikes be constructed two feet (0.61 m) higher than those for a "clean" channel.

Ideally, the dikes should be tied into a height of land on the upstream end and into an existing diking system on the downstream end. While it may be possible to tie the dikes into the sloping terrain at the upstream end, there is no logical tie-in at the downstream end, so they would terminate near where the Tongue River joins the Pembina. The land adjacent to the levees near the Red River would still be subject to overland flooding from the Red or Tongue Rivers.

The highway bridge across the Red River at Pembina and the railway bridge at Emerson in themselves have no impact on water levels in the area. However, the channel restrictions created in part by diking systems around the two communities may have a minimal impact on water surface profiles in the area.

Decision Support. One of the tasks initiated by the Task Force, in partnership with the Global Disaster Information Network, is the development of a virtual database for the Red River basin. The virtual database will provide a means of making data and information concerning mitigation measures, emergency response, and flood recovery available to governments, non-governmental organizations and the public.

The virtual database is a distributed database searchable over the Internet. Each contributing agency will continue to be responsible for maintaining and updating its own holdings and the related data documentation. Hundreds of relevant data sets held by dozens of agencies have been catalogued. Used in concert with a suite of models or model outputs and interactive tools, these data sets constitute a decision-support system. In effect the system would search for data, present or report data, export data to models and execute some models, and import and present results from models. Such a system must be developed in phases so that it can be tested and evaluated.

A prototype focusing on the Pembina basin is in the early stages of development. Specific flood management issues within the Pembina River basin addressed by the system will require the four following applications:

- Flood forecasting tools, including interpretation of official flood forecasts for both Canada and the U.S.
- Flood preparedness tools, to select appropriate structural and non-structural measures for reducing flood risk and flood damages, including hydrologic models to estimate runoff and hydraulic (or hydrodynamic) models to generate water elevation and flood-extent maps
- Optimization tools, including economic models to investigate possible modifications to flood control systems for minimizing economic loss
- Emergency management tools, including models to simulate, test and update emergency plans.

Grass Roots Involvement

Over the decades, a number of local interest groups have formed, only to fade away as the degree of concern over flooding issues in the Pembina area ebbed and flowed with the flood cycle. Today, there are a number of grassroots organizations, most notably the Red River Basin Board (RRBB) and the newly formed Pembina River Basin Advisory Board (PRBAB).

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The RRBB has three special task forces, including the Pembina River Watershed Task Force. The purpose of this task force was to ensure that the work being done in the Pembina watershed was compatible with the objectives of the RRBB. The work of this task force has been placed in abeyance pending the outcome of the work of the Red River Basin Task Force, the PRBAB, and others.

Like the RRBB, the PRBAB was established in 1997. However, the PRBAB has the more narrow focus of attacking flooding problems and associated issues along the Pembina River. Membership includes representatives from counties, townships and municipalities, state and provincial governments, conservation districts, and water management organizations throughout the basin.

The PRBAB is currently working toward the development of a water management plan for the basin. The Board serves as a valuable forum for the public presentation and discussion of new information on water management as it becomes available. As an example, the results of the Task Force's computer modeling of flood flows along the Pembina have been shared with the Board at public meetings. Scenarios proposed at those meetings have been incorporated into the model.

Conclusion 7: ***There is general recognition in the region that flooding in the lower Pembina River basin has been profoundly affected by the construction of dikes and of roads that act as dikes on both sides of the boundary. Rectifying the transboundary flooding consequences of these structures will require action in both countries and there appears to be a general readiness to take such action.***

Recommendation 27: ***The International Technical Working Group, formed in 1996 but currently inactive, should be re-activated to examine the findings of the hydrodynamic model. Working with local interests, such as the Pembina River Basin Advisory Board, it should develop, implement, and fund a solution that is sustainable in the long term.***

Recommendation 28: ***Given the transboundary nature of the basin and the potential for federal involvement in funding and monitoring any agreement, federal agencies from both countries should be engaged in this process as well.***

Recommendation 29: ***Changes in the road network and diking system in the lower Pembina basin should be modeled by the hydrodynamic model prior to implementation of any plan to ensure that there are no unintended consequences.***

Recommendation 30: ***The virtual database and decision support system prototype that the Task Force has begun to develop for the Pembina basin should be continued by relevant agencies in Canada and the United States.***

8

Hydraulic Connection at Lake Traverse

The low continental divide between the Little Minnesota River in the Mississippi River basin and the Red River in the Hudson Bay basin historically has allowed the waters of the two systems to mix occasionally during periods of flood. Several early residents reported being able to take advantage of a much-shortened portage in the region of Browns Valley when water levels were high during spring floods.

Transfer of water from one basin to another has become a major environmental concern in recent years as the introduction of new species into a watershed can cause enormous damage. For example, over 100 non-native species have been either intentionally or accidentally introduced to the Great Lakes. A number of these, including the zebra mussel, have quickly expanded their range into the Mississippi basin but have not yet crossed the continental divide to the Hudson Bay basin.

The Commission heard concerns that flood waters in 1997 moved between the Little Minnesota River in the Mississippi basin and Lake Traverse in the Red River basin. This movement had the potential for transferring unwanted species from one basin to another. The Task Force examined the issue of the hydraulic connection between Lake Traverse and Big Stone Lake to determine:

The Commission heard concerns that flood waters in 1997 moved between the Little Minnesota River in the Mississippi basin and Lake Traverse in the Red River basin.

1. the probable frequency of inter-basin connection;
2. whether the flood control infrastructure at Lake Traverse affected the frequency of this inter-basin connection;
3. whether this infrastructure should be modified or operated in a different manner to prevent the future transfer of water at this site; and
4. whether other structural measures should be constructed to prevent the future transfer of water at this location.

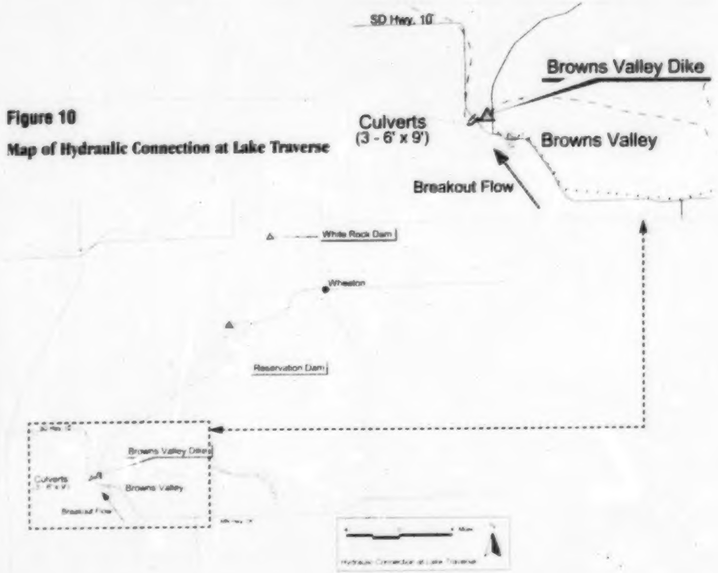
The Lake Traverse Flood Control Project was completed in 1941. It included the Reservation and White Rock dams at the outlet of Lake Traverse to the Bois de Sioux River (which flows into the Red River), and the Browns Valley Dike (forming part of South Dakota Highway 10) at the upstream end of Lake Traverse. The dike was designed to prevent high waters from backing into the city of Browns Valley or the Little Minnesota River. The Little Minnesota River flooded soon afterward, in the spring of 1943. Flood waters overtopped the left (north) bank of the Little Minnesota River, pooled upstream of the Browns Valley Dike, and eventually flooded parts of the city of Browns Valley. The dike was breached during the 1943 flood and remained breached until 1945, when culverts were inserted to allow possible overflows from the Little Minnesota River to escape northward to Lake Traverse.

The top elevation of the Browns Valley Dike is 987.0 feet (300.8 m), while the maximum regulated pool elevation in Lake Traverse is 982.0 feet (299.3 m). The invert or bottom elevation of the three open culverts (each one 6 feet (1.8m) high, 9 feet (2.7 m) wide, and 98.75 feet (30 m) long) is 974 feet (292.9m).

While studying this issue, the Task Force found that the continental divide at this location is formed by the left (north) bank of the Little Minnesota River rather than by the Browns Valley Dike. The minimum elevation of the north bank is approximately 983.9 feet (299.89 m).

Figure 10

Map of Hydraulic Connection at Lake Traverse



Construction of the flood control works in 1941 left the maximum regulated pool elevation of Lake Traverse at 982.0 feet (299.31 m). The highest water elevation recorded since 1941 was 982.21 feet (299.37 m), on April 16, 1997, while the lake was still covered with ice. Since the continental divide is at 983.9 feet (299.89 m), it is unlikely that water from Lake Traverse could have moved across it to the south and then entered the Little Minnesota River.

Before the flood control works were constructed, water levels in Lake Traverse would normally have been even lower than 982.0 feet (299.31 m), making it improbable that water flowed south across the continental divide at this point. The highest water level in Lake Traverse prior to 1941 was 977.3 feet (297.88 m), in the spring of 1916. Because construction of flood control works on Lake Traverse did not affect the elevation of the continental divide along the north bank of the Little Minnesota River, it is unlikely that these structures altered the frequency of inter-basin flows at this location.

The channel capacity of the Little Minnesota River in this reach is approximately 3,000 cfs (85 cms). Flow records indicate that channel capacity is exceeded during open river conditions (that is, when there are no ice jams), with a recurrence interval of between 1 in 10 years and 1 in 50 years (so that there is between a 10 percent and a 2 percent chance that the flow will be exceeded in any single year). However, the city of Browns Valley has a history of flooding related to ice jams, including the 1943 event, which led to the eventual breaching of the Browns Valley Dike. The artificially elevated stages resulting from ice jams likely increase the probability of the breakout flows. Once channel capacity is exceeded, excess flows can move either to the south to rejoin the Little Minnesota River (thus staying within the Mississippi basin) or across the continental divide to the north, into Lake Traverse within the Hudson Bay basin. During extremely large flood events, it is possible for excess flows to move both to the south and to the north.

Aerial photos suggest that the Hudson Bay and Mississippi basins were not hydraulically connected during the flood of 1997.

Flow records indicate that channel capacity was exceeded during the 1997 flood. However, aerial photographs taken during the fall of 1996 and compared with similar photographs taken during the spring of 1997 indicate that excess waters escaped from the south bank of the Little Minnesota River and remained within the Mississippi basin. This would suggest that the Hudson Bay and Mississippi basins were not hydraulically connected during the flood of 1997.

Long-time residents in the city of Browns Valley are familiar with the historical breakout flows from the Little Minnesota River that occurred during 1943 and again in 1993. Local residents observed northward flow through the culverts in the Browns Valley Dike during spring flooding in 1997. However, it is not known whether these flows originated from local runoff or breakout from the Little Minnesota River. Previous flood control studies for the city of Browns Valley in 1972 indicated that inter-basin flows could be eliminated, for

Eliminating this single pathway in the region of Browns Valley should only be considered as part of an overall, integrated approach to managing non-native species.

example, by removing the culverts through the Browns Valley Dike, but a diversion or additional flood protection levees and pumping facilities would need to be constructed. The approximate 1999 cost of these measures is $1.5 million. Other physical means may also be available to prevent future inter-basin flow at this location, but these require further investigation.

Hydraulic connections are only one of a number of mechanisms by which unwanted non-native species can migrate between adjacent basins. Eliminating this single pathway in the region of Browns Valley should only be considered as part of an overall, integrated approach to managing non-native species. Although the potential for exotic species to enter the Red River basin from the Little Minnesota River appears remote, it deserves attention because of the potentially severe consequences and the coordinated actions both federal governments are taking on the exotic species issue in some regions.

Recommendation 31: ***Engineering studies should be immediately undertaken to examine all means of eliminating the potential for the hydraulic inter-basin connection in the vicinity of Browns Valley. Governments should then implement the most feasible option. During the interim, the Little Minnesota River system should be closely monitored for undesirable species. If such species appear, immediate action should be taken to prevent their transfer to the Red River basin.***

Since benefits accrue basin-wide from coordinated actions taken to prevent the movement of non-native species between adjacent basins, local governments should not be held responsible for costs associated with monitoring or implementing corrective measures. While the U.S. Army Corps of Engineers will need to take the lead role in implementing this recommendation, cost-sharing options should be negotiated with Canada because of the basin-wide benefits.

Any additional increase in the maximum regulated pool elevation of Lake Traverse beyond the present 982.0 feet (299.31 m) would increase the probability that waters from the Red River basin could begin to cross the continental divide to the south and enter the Little Minnesota River.

Recommendation 32: ***Any modification to existing operating plans or physical structures associated with Lake Traverse that could increase pool elevation must be accompanied by features that eliminate the southward movement of water into the Little Minnesota River.***

9

Lake Winnipeg Water Quality

Water quality studies undertaken during the 1997 Red River flood identified several concerns that warranted further investigation. Follow-up studies conducted in 1998 and 1999 focussed on persistent toxic materials that may have been transported to Lake Winnipeg during the flood.35 Additional work was also done on the potential damage to plant nutrients and on contaminants associated with suspended sediments carried to Lake Winnipeg during the 1997 flood.

Lake Winnipeg provides livelihood to about 850 licensed commercial fishers, their families, and employees.

In surface area, Lake Winnipeg is the world's tenth largest freshwater lake (23,750 km^2 or 9,173 square miles). It receives drainage from a catchment area of 977,800 km^2 (377,674 square miles), of which 116,500 km^2 (44,998 square miles) is the Red River basin. The Red River empties into Lake Winnipeg about 60 km (37 miles) north of Winnipeg. Lake Winnipeg provides recreational opportunities to thousands each year, has excellent beaches, and provides livelihood to about 850 licensed commercial fishers, their families, and employees. For many commercial fishers of First Nations origin, the Lake Winnipeg fishery provides the primary or sole source of income.

Flood-Related Plant Nutrients

Large amounts of phosphorus and nitrogen were carried into Lake Winnipeg during the flood. Notwithstanding the amount deposited, it is not possible to tell how much this flood may have stimulated algal growth beyond normal, or whether there were more or fewer deposits than in other recent Red River floods, such as in 1979. The nitrogen load appears to follow the historical relationship with flow, while the phosphorus load may have increased by about 12 percent. This indicates either that the historical relationship did not accurately predict phosphorus loads for major floods or that changed land-use practices in recent years have contributed to greater relative losses of phosphorus.

Trace Elements

Trace elements associated with suspended sediments were monitored during the 1997 flood. Follow-up work in Lake Winnipeg during the winter of 1998 examined the concentration of trace elements in lake bottom sediments. Although 14 trace elements were analyzed, environmental quality guidelines published in 1999 by the Canadian Council of Ministers of the Environment (CCME) are available only for chromium, copper, zinc, mercury, cadmium, and arsenic. Many of the samples of cadmium, chromium, arsenic, and zinc exceeded the guidelines, but it is uncertain whether these concentrations have any biological effect. It cannot be determined with certainty whether the observed metal levels in the bottom sediments are due to the Red River flood or to previous or ongoing contributions, or whether the concentrations reflect the normal ranges in Lake Winnipeg.

Trace Organics

Water quality monitoring during the flood identified traces of fresh toxaphene in water and suspended sediments.

Toxaphene is a pesticide that was widely used in North America until it was generally banned in Canada and the United States in 1982, with some restricted uses allowed in the United States until 1990. During the flood of 1997, a small quantity of toxaphene is presumed to have been lost from a flooded agricultural warehouse near Grand Forks, North Dakota. Innovative analytical techniques were used to differentiate between normal background concentrations of aged toxaphene and concentrations of new or fresh toxaphene recently released to the environment. Water quality monitoring during the flood identified traces of fresh toxaphene in water and suspended sediments in samples collected from the Red River at the international border on May 5, 1997, (8.4 nanograms per litre (ng/l)) and near Winnipeg 15 days later (4.6 ng/l). Concentrations in water quickly returned to normal background levels of about 0.7 ng/l by the end of May. An estimated 46 kilograms (101 pounds) of new toxaphene was identified in Lake Winnipeg following the 1997 flood.

The implications for Lake Winnipeg wildlife consumers are not considered significant.

Toxaphene concentrates in the edible flesh of sport and commercial fish, and has health implications for wildlife and humans. CCME recently published a tissue residue guideline for toxaphene—6.3 nanograms per gram (ng/g) wet weight—to protect wildlife that may consume contaminated tissue. Toxaphene concentrations in the muscle tissue of various fish species collected during 1997, 1998, and 1999 from the Winnipeg Beach and Riverton regions of Lake Winnipeg were within the CCME guidelines, except for walleye collected in 1999 from the Winnipeg Beach area, which contained mean toxaphene concentrations of 8.05 ng/g. The implications for Lake Winnipeg wildlife consumers are not considered significant. The guideline represents an estimation of the safe concentration of toxaphene to protect avian fish eaters, divided by a factor of ten for uncertainty. The estimated safe concentration for the protection of mammalian predators is considerably higher, at 348 ng/g wet weight.

Ontario's Ministry of Environment has developed fish consumption guidelines for toxaphene in edible muscle tissue. The concentrations in the muscle tissue of Lake Winnipeg fish are well below Ontario's fish consumption guidelines.

The data on toxaphene in Lake Winnipeg fish is not well understood because there is a complex relationship between toxaphene concentrations in biological tissue and factors such as age, length, weight, lipid or fat content, differences between species of fish, and differences between locations within the south basin of Lake Winnipeg. Toxaphene concentrations seem to have increased in fish tissue since 1997. It is expected, however, that concentrations will begin to decline slowly within the next several years.

Toxaphene concentrations seem to have increased in fish tissue since 1997. It is expected, however, that concentrations will begin to decline slowly within the next several years.

Other trace organics, such as PCBs and DDT, were mobilized during the 1997 flood. Unlike toxaphene, however, only old or existing sources of materials were transported with the flood peak. It appears that PCBs and DDT, like toxaphene, generally increased in fish tissue following the 1997 flood. However, concentrations remain well below consumption guidelines developed by Health Canada for the protection of human health.

Although the flooded warehouse in the United States probably contributed to the new traces of toxaphene found in Lake Winnipeg, similar losses could have occurred within Canada, or from flooded on-farm storage in either country. North Dakota, Minnesota, and Manitoba have well-established voluntary programs in place to collect used pesticide containers and other household or on-farm hazardous wastes. However, there appears to be no systematic program in any jurisdiction to verify the efficacy of the voluntary programs or to eliminate the potential for the accidental release of banned hazardous chemicals through enhanced voluntary or mandatory measures.

Recommendation 33: Governments should take immediate steps to ensure that all banned materials such as toxaphene are removed from storage areas in the Red River basin and that potentially hazardous materials are not stored in the 500-year floodplain. Reasonable quantities of such substances could be maintained in the floodplain for immediate use.

Recommendation 34: Governments should continue to monitor toxaphene in the Lake Winnipeg ecosystem until concentrations decline to pre-1997 levels.

10

Data and Decision Support

Successful floodplain management and flood preparedness require reliable and accessible data. As part of its review of available information, the Task Force consulted data users in the Red River basin.[56] These users expressed a need for major improvements in the ways they could get data and in the means for disseminating it to the public, for more efficient data exchange between agencies involved in floodplain management, and for greater database integration within the basin. The Task Force itself faced obstacles in assembling the data it needed for an analysis of flood issues. In short, the fragmented and incomplete information available is a major obstacle to better flood planning and preparedness.

The need for access to diverse data sources became apparent when the Task Force was developing some of its own models. In the process of meeting its data needs, the Task Force felt that it had an opportunity to help improve accessibility to the various flood-related data sources in the basin. Through its consultants, it assembled information about existing paper and electronic records and collected new data. Because the multi-jurisdictional, international setting of the Red River basin makes a central database impractical, the Task Force made use of existing communications and computing technology to begin development of a distributed virtual database. The information would be available electronically in an integrated form, but each of the underlying databases would continue to be maintained and operated by the relevant agencies.[57]

The fragmented and incomplete information available is a major obstacle to better flood planning and preparedness.

The ultimate goal is a distributed database that makes available for all users data on floodplain management and flood disaster activities, including the development of computer models. The integration of computer models with the virtual database has great potential for creating a powerful means to analyze flood-related problems in the basin. The concept of a binational information base for floodplain management sparked interest from the Global Disaster Information Network (GDIN), a program within the U.S. federal government. The goal of GDIN is to foster effective sharing of disaster-related information through the use of evolving information technologies. GDIN has been working in partnership with the Task Force throughout the study on the development of a database, networking, and decision-support system.

Global Disaster Information Network

GDIN is an interagency effort within the U.S. government to integrate information relevant to disasters and to make that information available rapidly and reliably to whoever can help reduce loss of life and damage.

The network will function via the Internet, U.S. federal intranets, and other communications media. It will be used to enhance training and communication among people with common interests and will be designed to broadcast and provide information on request.

The Red River Basin Disaster Information Network (RRBDIN) is a pilot project to test the GDIN concept and promote cross-border information sharing.

The primary responsibility for mitigating and responding to disasters lies with local residents. Design and operation of the Red River Basin Disaster Information Network, therefore, will strive to involve various stakeholder interests within the Red River Basin.

The GDIN initiative is working in partnership with the Task Force and is partially funding development of the virtual database and decision-support system initiative.

The Task Force and the GDIN have launched the Red River Basin Disaster Information Network (RRBDIN) to draw together data providers and users in a single online source to locate and use information on floodplain management issues in the basin. Ultimately the Task Force foresees integration of databases and models into a decision-support system (DSS) for managers and user groups throughout the basin.

> **Conclusion 8:** ***Further improvement and maintenance of the Red River floodplain management database is required. Federal, state and provincial governments and local authorities must maintain a high level of involvement in further database development and in improving data accessibility.***

Hydrometeorological network augmentation

The most basic information for flood planning and preparedness is hydrologic and hydraulic data. Between the 1979 and 1997 floods there were considerable reductions in the stream gaging and meteorological networks used in flood forecasting as agencies underwent budget cuts. This was not acceptable and the Task Force's interim report made a number of recommendations concerning the state of the hydrometric and meteorological networks within the basin.

In Manitoba, the hydrometric network is being expanded, modernized and floodproofed. The work began in 1999 and is scheduled for completion in 2001.

Development of an improved meteorological network began in 1999, to overcome deficiencies in Environment Canada's climatological network and to meet increased demands for services both in the agriculture and water resource areas. By 2001, the network should provide information on precipitation, temperature, soil moisture, and other parameters for each township in the Canadian portion of the basin..

The hydrometric network in the United States, Minnesota, and North Dakota has been modernized or floodproofed since the 1997 flood.

Completion of the hydrometric and meteorological networks will largely satisfy data needs for flood forecasting and water management in general. Additional satellite data, airborne data, and weather radar data may also be needed. However, the various data sets from the expanded networks should provide the information needed for effective hydrologic modeling and forecasting in the near future.

Completion of the hydrometric and meteorological networks will largely satisfy data needs for flood forecasting and water management in general.

> **Recommendation 35:** ***Hydrometric and meteorological data networks necessary for flood forecasting should be improved and maintained in a state of readiness to forecast future floods.***

Datum Standardization Issue

A frequently heard comment at the Red River Basin Information/Data Needs Assessment Workshops was that everyone needs to use the same gage reference system so that each entity can understand how any reported water elevation (stage) along the length of the Red River relates to its own situation.38 Changes in procedure that result in river-stage reporting as gage height (local datum) instead of elevation (standard datum) could cause numerous problems in implementation for both agencies and community groups.

The Task Force explored some of the basic issues in a report.[39] One of the findings related to the different vertical reference systems (datums) used in Canada and the United States. Because the channel slope in the border area is only 0.1 to 0.2 feet per mile (1.89 to 3.78 cm per km), the small difference between the Canadian and American reference systems of 0.15 feet (4.57 cm) could be significant for hydraulic models of the area. Adjustments should be made using commonly available conversion software.

Other types of differences that must be reconciled include the following:

- River stage data and forecasts are already reported as elevations in Canada, but in the United States this information is presented in terms of gage height.
- Most common maps used in the United States and Canada (such as flood insurance and topographic maps) use different datums and are not standardized to the most current and accurate datum.
- The U.S. government has affirmed NAVD88 as the official civilian vertical datum for surveying and mapping, but the Canadian government has not yet done so.

> **Recommendation 36:** ***New geographically related data collection in the United States should be in accord with the North American Vertical Datum of 1988.***

Recommendation 37: ***For consistency and accuracy data used in models should take into account the differences in data at the border. Because datum conversions can affect data accuracy, any conversions between standards should be noted and reported along with the data.***

Recommendation 38: ***U.S. National Geodetic Survey and the Geodetic Survey of Canada should convene a forum of datum experts in the year 2000 to discuss Red River Basin datum issues and develop a long-term transition plan.***

Virtual Data Base

The Task Force has developed the Red River Basin Virtual Database (RRBVDB) so that Red River basin data managed by Canadian and U.S. agencies can be accessed more easily. The intent is to provide interested parties throughout the basin with information related to emergency response activities, planning activities to prevent and protect against floods, and flood-recovery activities. All interested governmental organizations, non-governmental organizations, and the public will have access to the information and can contribute additional data to the Virtual Database.

The virtual database will be searchable via the Internet by such headings as data type, data holder or owner, and location.

As the virtual database is distributed, individual databases remain housed in their home agencies. This makes it unnecessary for data providers to submit regular updates to a centralized data clearinghouse. Users will be able to locate required data quickly, find a description of the contents and limitations of the data, and retrieve data sets of interest. The virtual database will be searchable via the Internet by such headings as data type, data holder or owner, and location.

The Task Force completed the first stage of building a searchable database for the basin, which identified all information providers who could contribute flood-related information. Metadata (data about data) describing data sets by availability and usefulness for various types of analyses were then identified or prepared. Metadata provides a method for capturing and documenting long-term memory about data and must be a prerequisite for any data set catalogued in the RRBVDB.

The 99 agencies and organizations contacted in the United States, including 65 with some form of Internet capability, yielded 384 data sets.[40] Metadata already exist for many of these data sets, especially within federal and state agencies. Limited funding curtailed further development planned for U.S. metadata.

Canadian metadata were compiled from 34 agencies, in accord with the U.S. Federal Geographic Data Committee Content Standards for Digital Geospatial Metadata. The Task Force catalogued 121 data sets. Internet data services vary: 26 agencies have a corporate or departmental Web site, 5 are actively promoting data services over the Internet, and 3 currently use the Internet for e-mail and have browse access only.

In particular, the cost-recovery policies of some (Canadian) agencies, especially in federal departments, makes public dissemination of data too costly to be practical.

Many agencies plan to move from a passive and static web-based environment to a more interactive and dynamic environment when the information-sharing and application-use capabilities of the Internet become stronger. The next generation of Web sites will incorporate facilities in which products and services are offered to business partners, suppliers, contractors, and the public at large.

While there is support for the RRBVDB among the agencies with appropriate data sets for flood management in Manitoba, issues remain concerning public access to the data. Foremost is the security of the internal network. No agency is willing to risk the integrity of the original data sets by giving the public unlimited online access. Other issues arise from the conservative "data culture" in Canada. In particular, the cost-recovery policies of some agencies, especially in federal departments, makes public dissemination of data too costly to be practical.

These Canadian policies have hampered the work of the Task Force. The perceived need to recover the costs of data sharing stifles the public and private creativity needed to respond to the flood threat and ultimately puts public safety at risk. By increasing communication and coordination, an operational RRBVDB offers the opportunity to increase partnering efforts for sharing the costs of data development. Increased collaboration of this type would ultimately result in the greatest benefit to the public good in terms of lower costs and greater access to information.

Recommendation 39: ***All key data providers in Canada should make available at no cost and with no restriction the data sets necessary for the Red River floodplain management and emergency response, and regional or basin-wide modeling activities.***

Recommendation 40: ***Data providers should remain responsible for maintaining and replicating the data sets.***

Table 11

Key Data Providers*

Canada	United States
1. Manitoba Conservation Water Resources Branch	1. U.S. Geological Survey 2. National Weather Service
2. Environment Canada	3. U.S. Environmental Protection Agency
3. Manitoba Emergency Management Organization	4. Minnesota Land Management Information Center
4. City of Winnipeg Water and Waste Department	5. North Dakota State Water Commission 6. Minnesota Department of Natural Resources
5. Manitoba Highways and Transportation	7. Minnesota Department of Transportation 8. North Dakota Department of Transportation

Task Force Data Collections

Time Series Flood Inundation: The 1997 flood is especially difficult to understand because of the complex weather conditions before and during the event, its long duration and multiple peaks, ice, and its unpredictable overland flow. To reconstruct the flood, evaluate the total area inundated, and help calibrate models, the Task Force analyzed RADARSAT imagery taken during the event. The RADARSAT satellite, which can image through clouds and rain, works equally well by night or day and can collect data at almost any point on the globe. RADARSAT produces monochrome images with resolution of up to 25 m (82 feet). Each image can encompass a spatial extent of approximately 100 by 100 km (62 by 62 miles), thus providing broad aerial coverage. The satellite takes less than two days to revisit sites at the latitude of the Red River basin.

The Task Force obtained 26 RADARSAT images collected between April 4, 1997, and June 7, 1997. Images of the flood from south of Winnipeg to approximately 15 miles (9.3 km) south of Wahpeton and Breckenridge have been geocoded and mosaiced.

Stage-damage Curves: The development of alternative flood protection works requires an estimate of the cost of damages from floods of a magnitude equal to or greater than the 1997 flood. This means developing a model for stage-damage calculations, or stage-damage curves, which represent the flood damage likely at differing depths. Such modeling can also aid in decision making during emergencies and in the flood-recovery phase. The Corps of Engineers has updated U.S. stage-damage curves to reflect current economic data. In the 1997 flood, according to U.S. Department of Commerce estimates, the total damages in the U. S. portion of the Red River were approximately $4 billion, of which $3.6 billion was incurred in the immediate vicinity of Grand Forks and East Grand Forks.[41]

The development of alternative flood protection works requires an estimate of the cost of damages from floods of a magnitude equal to or greater than the 1997 flood.

Figure 11

Southern Manitoba, May 1997

In Canada, the Task Force updated the depth-damage relationships for Winnipeg and the area south of the city.[42] The work proceeded in two phases. First, based on a sample of damage data (186 of some 5,000 damaged structures) provided by Manitoba Emergency Management Organization (MEMO), relationships of damage to depth of flooding were calculated. Damages were calculated as a percentage of market value of the structure. Stage-damage curves were calculated for different classes of structure and, as well, for agriculture and infrastructure damages.

Following that, the curves were used to create a number of map products using a geographic information system. The location and elevation of 60,000 buildings were incorporated into the GIS to enable visualization of damage under various scenarios. The resulting model can be used for planning and design of flood control measures and for flood recovery purposes following future floods. One specific calculation involved damage estimates for a flood of 1826 magnitude.

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The Task Force consultants estimated that the total damages to Manitoba in a flood similar to that of 1997 would be $235.6 million for structural damages, $14.7 million for agricultural damages, $47.5 million for infrastructure damages, and an estimated $67.4 million damage to the city of Winnipeg. For a flood of 1826 magnitude, the damages would be $7.94 billion, $7.47 billion to the city of Winnipeg,* $336.8 million structural.

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* *A key finding from Task Force studies is that there are many important data providers. A data set is not necessarily less "key" just because it is not available for the whole basin. There is a danger in focusing exclusively on the major data providers and leaving out the smaller or regional ones, which need to be included. See Phase Four Technology Management Corp. (1998).* Red River Basin Virtual Database: Data Assessment Report (Canada) *(http://www.ijc.org/boards/rrb/CA_data1.pdf), and Rust Environment & Infrastructure (1999).* Red River Basin Virtual Database: Data Assessment Report *(U.S.A.)*

* *A more rigorous assessment of the City of Winnipeg damage was provided in the KGS study* Winnipeg at Risk, Part 3. *The estimate generated by this study is lower ($5.8 billion) since the depth-damage relationships were derived from a more conservative approach than the MEMO derived depth-damage curve.*

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Analysis of future flood control measures, operation of existing flood control structures, and evaluation of different hydrologic scenarios depends on adequate topographic representation of the basin.

$66.5 million agricultural, and $65.6 million for infrastructure damages in the valley.

High-Resolution Digital Elevation Models: One of the main objectives of the Task Force was to coordinate and investigate requirements and capabilities for a detailed Digital Elevation Model (DEM) for the Red River basin.

Analysis of future flood control measures, operation of existing flood control structures, and evaluation of different hydrologic scenarios depends on adequate topographic representation of the basin.

Because of the costs of acquiring high-resolution elevation data, the Task Force was unable to develop a detailed basin-wide DEM. A variety of activities undertaken, however, do provide partial DEM data and lay the groundwork for further acquisition of high-resolution elevation data.

The U.S. Geological Survey and the Canadian Centre for Remote Sensing cooperated to create seamless "best available" digital elevation data. A DEM for the Canadian section of the Red River basin was generated from 1:30,000 aerial photographs and 1:60,000 digital ortho-photographs of the basin. The majority of the best available DEM for the U.S. portion of the basin has been developed from USGS 1:24,000 topographic maps.

Within a portion of the Pembina basin, the Task Force tested various techniques for obtaining digital elevation data, including Global Positioning System-based ground surveys and aerial survey systems such as Lidar (Light Detection And Ranging) and IFSAR (Interferometric Synthetic Aperture Radar). These three technologies were compared in terms of costs, data accuracy, and other DEM production considerations.

The Task Force found that airborne laser and radar mapping can be a fast, reliable, and cost-effective method of obtaining three-dimensional data for the creation of a DEM. These data can be accurate to within the range of 0.5 meters to ±15 centimeters (1.6 feet to ± 6 inches) depending on the technique used.

Further work toward compiling a basin-wide elevation model will require considerable resources, but it can be best accomplished through a coordinated effort that involves sharing of expertise, funds, and data. Opportunities for resource sharing should be coordinated using RRBDIN communication tools to the extent possible.

Drawing on the expertise of hydraulic and hydrologic modelers, the needs for a basin-wide variable resolution DEM were identified:

- detailed elevation of infrastructure within the floodplain, with vertical accuracy of 2 inches (5 cm), including roads, railways, main drains, and Red River tributaries;
- detailed elevation for specific urban locations, with vertical accuracy of 4 inches (10.6 cm);
- less detailed (3 feet or 1 m) elevation data, preferably for the entire 1826 flood high-water area and alternatively for the 1997 flood high-water area; and
- detailed DEM of ten areas, approximately 25 square miles (65 km^2) each, for quality control of DEM extrapolation techniques for the rest of the basin.

The Task Force required the contractor who collected Canadian data for the Task Force to provide the data sets free of any use or sharing constraints.

For the fairly new Lidar and IFSAR technologies, the contractors doing the collection often license the data sets. By restricting the sharing of this important data set, this practice is counter to the data-sharing philosophy of the RRBDIN. The Task Force required the contractor who collected Canadian data for the Task Force to provide the data sets free of any use or sharing constraints. This approach made the data freely available and did not result in added cost to the data collection effort.

Recommendation 41: *Development of the digital elevation model for the Red River Basin should be completed by collaborative initiatives of the relevant agencies.**

The Red River Basin Disaster Information Network and Decision Support System

The Task Force and GDIN interests have initiated the Red River Basin Disaster Information Network (RRBDIN) as a means of providing decision-making tools for floodplain management, disaster relief, and mitigation. Because the system is Internet-based, necessary data will be readily available to users. Especially important is the ability of such a system to deliver information during an emergency. The RRBDIN is being developed to provide an interactive and iterative process of building basin-wide information resources and to improve communications and enhance cooperation.

The network consists of a growing community of RRBDIN members (individuals and organizations), who will use and help develop several tools incorporated into an Internet Web page (http://www.rrbdin1.org). The Web page is evolving as the members test and direct its contents. It includes communication tools, searchable lists of organizations and points of contact, a document library, policies and procedures, a searchable catalog of available databases, map presentation and search tools, analysis tools (hydrologic and hydraulic models), a bulletin board, and other information resources.

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* *In Canada the relevant agencies could be Manitoba Conservation's Water Resources Branch and Agriculture Canada's Prairie Farm Rehabilitation Administration; in the U.S. the Federal Emergency Management Agency, the Corps of Engineers, and the states of Minnesota and North Dakota. For specific local or regional areas, affected counties, watershed districts, and municipalities should contribute as well.*

The RRBDIN is envisioned as a single online source where people can locate information and data relating to water management issues in the Red River basin. The types of interaction made possible by this technology should lead to stimulating and creative thinking, and ultimately a growing knowledge base to benefit all Red River basin stakeholders long after completion of this IJC study. It is hoped to involve the broadest range of interested individuals in an exchange of data, information, knowledge, and ideas through the free sharing of relevant databases and participation in various networking opportunities. The vision is for the RRBDIN to become a trusted and dependable resource for informed decision making that is built upon and maintained by a strong network of cooperating individuals, organizations, and agencies.

Development of an information network that ties together a broad range of Red River basin agencies and interests could improve basin flood management.

The Task Force believes that development of an information network that ties together a broad range of Red River basin agencies and interests could improve basin flood management. Existing information systems are designed for individual agency problems and requirements, which result in stand alone "islands of automation." Advances in information technologies enable greater sharing and processing vital information. A decision-support system (DSS) can connect these "islands" and allow decision-makers and others to ask floodplain management and preparedness questions and carry out automated analyses. The DSS brings together models and the virtual database.

The RRBDIN provides the framework from which the DSS is being developed. The DSS is being formed in several stages, beginning with a prototype for the Pembina sub-basin that uses a small number of databases. Following the testing of the prototype, an advanced prototype will be developed, and finally the fully functional DSS.

The DSS can be understood as a collection of scenarios, or stories, that define problems (for example, flood risk assessment, real-time status of ice or debris jams, and disaster emergency response). Each scenario describes the problem, shows how the user would interact with the DSS, and sets out the data, model, and output requirements (such as database table, map, or chart).[45]

The cross-border approach presents a unique opportunity in which to showcase a suite of technical and institutional challenges.

Interest in the effort continues to grow, as evidenced through discussions with the Open GIS Consortium and the National Science Foundation. Organizations such as these are interested in the concept for a variety of reasons. For instance, the Task Force work is providing the context in which to test and evaluate new modeling techniques, communication protocols, advanced sensing capabilities, fusion techniques and interoperability procedures. The cross-border approach presents a unique opportunity in which to showcase a suite of technical and institutional challenges. Although the Task Force work has achieved a fairly high level of interest, more work is needed in order to reach a stage where a truly robust prototype can be demonstrated.

The development of the RRBDIN was predicated on an understanding that the Task Force would stay active through the year 2000 and that matching funds from the Global Disaster Information Network (GDIN) would continue. These funds have not materialized. It is estimated that an additional $300,000 (US) will be needed to carry the RRBDIN development through December 2000. By that date a prototype DSS will be available. Also, a dynamic virtual data set will be posted that will allow for basin-wide geo-spatial queries to be made. The various modules that are displayed on the RRBDIN Web site will be functional and additional recommendations based on user feedback will be incorporated into the system.

The RRBDIN holds particular promise by promoting the most advanced collaborative technologies. It would be most unfortunate to see these developmental activities curtailed at this critical stage.

It would be most unfortunate to see these developmental activities curtailed at this critical stage.

Recommendation 42: *Relevant federal, provincial, state agencies and transboundary agencies should meet to determine the interest in continuing the work of RRBDIN and if there is agreement to continue it, draw up a funding and action plan to ensure its continuation.*

Virtual Forum

An important feature of the RRBDIN is its Virtual Forum. The concept provides for live discussion rooms where roundtable meetings, presentations on specific topics, or mutual help sessions can be held via the Internet. It can also distribute discussion lists so that comments and viewpoints can be aired at the convenience of the contributor. Workshop topics have included:

- Flood Forecasting Today and Tomorrow
- Recent Developments in Remote Sensing for Disaster Monitoring
- The International Flood Mitigation Initiative
- International Flood Mitigation Initiative (IFMI) Update
- A Process for Developing an International Watershed Board
- Issues in Professional Floodplain Management: The Association of State Floodplain Managers
- Cross-Border Issues in Disaster Response
- Women, Work, and Family in the 1997 Flood: Ten Lessons Learned
- The Role of Technology for Floodplain Management in the Next Millennium

Transcripts of the online workshops and other background information are available from the Web site.

This Virtual Forum capability is also available for meetings and on-line discussions by any group in the basin. The Pembina River Technical Committee has used the forum to hold a number of coordination meetings.

> **Recommendation 43:** ***A decision on whether to continue operation of the Virtual Forum should be included in the discussions on the continuation of the RRBDIN.***

11

Hydrologic and Hydraulic Modeling

Mathematical models of the Red River basin play an important role in forecasting floods, determining the extent of flooding, and planning for future floods. Experience during the 1997 flood demonstrated that improvements to existing models were needed, especially to account for overland flows. This chapter describes progress made on improving flood forecasting models and developing hydrodynamic models for the basin, and makes recommendations for further development.

Hydrology

The Red River, geologically a young river, can be described as having a very low gradient, slightly entrenched, meandering, silt-clay dominated, riffle-pool channel with a well developed, stable floodplain. Despite some slumping along the riverbanks, the meanders are generally stable.[44] The Red River rises slowly during a flood and is slow to recede. Flooding along the main stem, while relatively predictable, tends to be of long duration.

Major floods are inevitably spring floods, a consequence of conditions in the previous fall and winter and of conditions during the snowmelt. In 1997 the necessary preconditions for a flood were established with a wet fall, heavy winter snows and a late season blizzard. The flood could have been much worse had there been significant spring rains.

Flood forecasting is a well-established art in the region, with forecasts provided by the National Weather Service (NWS) in the U.S. portion of the basin and by the Manitoba Water Resources Branch in Manitoba. Both agencies used similar forecast techniques during the 1997 flood and exchanged information on a continuing basis. The 1997 flood pointed out the need for modifications to forecast procedures and to the way forecasts are communicated to the public. This section will review the changes in forecasting procedures since the flood and describe the current work on basin hydrology.

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Flood Forecasts

In general, improvements in flood forecasting have been directed at updating existing procedures and improving the physical basis for the forecasts to reduce the dependence on statistical relationships. A number of tasks have been accomplished, including expanding the data networks to support the forecasts. These network improvements are described in Chapter 10.

United States. The technical procedures used by the U.S. National Weather Service (NWS) to produce forecasts for the Red River have been examined in detail. Several efforts to improve on these procedures are under way.[45] These include:

- developing a dynamic routing hydraulic model (FLDWAV) for the Red River;
- reviewing some of the unusual flow paths that water took during the 1997 flood to add an empirical estimate of these overland flows to the NWS models;
- modifying the NWS forecast software to provide a more explicit warning when a rating curve extension is in use;
- reviewing the established flood stage for every forecast point on the Red, along with the associated detailed information about flood forecast services and flood impacts;
- recalibrating the Red River forecasting system by means of more complete historical data and models that are compatible with the latest NWS forecast methods;
- developing an enhanced system for analysis and use of snow information; and
- analyzing the existing flood outlook procedures to determine whether a useful estimate can be provided of the chances that the outlook flood crest will be exceeded.

Until recently, the NWS used an Antecedent Precipitation Index (API) technique in calculating soil moisture inputs to Red River forecasts. This is a statistical procedure based on previous experience. The NWS has now implemented a continuous streamflow simulation model, known as the Sacramento soil moisture accounting model, that is physically based and can be applied to individual sub-basins. The model has been running in parallel with the API for a year and will be introduced to forecasts in the spring of 2000.

Work is also under way to improve regional precipitation estimates at the Mayville, North Dakota, radar site by examining archived data and performing adaptable parameter optimization and statistical evaluations. These results should be transferable to other radar sites in the Red River basin.

Advanced Hydrologic Prediction System (AHPS) is ideally suited to forecasting in the Red River basin where floods are generally slow to develop.

Nationally, the NWS has started to implement an Advanced Hydrologic Prediction System (AHPS) which takes into account the relative uncertainty in hydrologic variables. The system takes into account long-term changes in variables and is thus ideally suited to forecasting in the Red River basin where floods are generally slow to develop.

Recommendation 44: *The U.S. National Weather Service should implement its Advanced Hydrologic Prediction System in the Red River basin as an early priority.*

Canada. In Manitoba, efforts have focused on improvements to the forecast networks and implementation of the MIKE 11 hydraulic model described below. Data from the 1997 flood was used to extend existing flood forecasting relationships.

Manitoba's River Forecast Centre uses an index model to predict runoff volume and peak discharge at Emerson, treating the entire U.S. portion of the basin as one basin for computational purposes. Daily predicted flows at Emerson are routed together with daily predicted flows for the 13 Manitoba tributaries, including the Assiniboine River. Following the 1997 flood, all the statistical relationships for the Manitoba tributaries were updated and extended to incorporate the unusually high soil moisture conditions.

Improved channel routing procedures were developed and adopted for the Pembina and Roseau Rivers, the two major tributaries shared by both countries. Flood routing on the main stem from Halstad, Minnesota, to Winnipeg was also examined.

Canada is an automatic beneficiary of any forecast improvements made in the much larger United States portion of the basin. For the most part, needs in Manitoba relate to improved tributary runoff models and flow routing.

Canada is an automatic beneficiary of any forecast improvements made in the much larger United States portion of the basin.

Communication of Forecasts. The NWS currently releases two flood outlooks to the public. The crest value in the first is based on the pre-runoff snow water equivalent only, while the second is based on snow water equivalent plus normal precipitation through the runoff period. The Manitoba Department of Conservation (Water Resources) outlook uses three figures, one based on normal weather conditions through the runoff period and others based on less favorable conditions (upper decile forecast) or more favorable conditions (lower decile forecast). Each agency therefore has one equivalent forecast for normal conditions and one forecast that is lower than normal (but not identical); in addition, the Department of Conservation has one that is higher than normal. There is some public confusion about the various forecasts, particularly as they are not released at exactly the same time.

The National Weather Service is considering public release of the water equivalent plus normal crest value and second crest value based on a higher percentage of normal precipitation. When the Advanced Hydrological Prediction System is implemented in the Red River basin, it will produce probabilistic forecasts.

It will be possible in the future to make very precise site-specific forecasts to aid basin residents and emergency workers.

That said, the existing and proposed forecasts are aimed at forecasting elevations at specific basin communities. With the development of accurate digital elevation models, highly detailed geographic information systems, and hydrodynamic models capable of simulating overland flow, it will be possible in the future to make very precise site-specific forecasts to aid basin residents and emergency workers. Such forecasts will present new communications challenges for forecast authorities.

The Task Force, following up on its recommendations on improving flood forecasting communications in the 1997 Interim Report*, examined means to ensure a common understanding of flood forecasting activities among the different basin jurisdictions and to communicate more effectively to the public.

> **Recommendation 45: *A binational Red River Flood Forecasting Liaison Committee should be established by government to improve communications among forecasters and with the public.***

See box on page 109 for proposed terms of reference for the Committee.

Hydrologic Models

A number of the many models developed to simulate hydrologic processes in a watershed have been applied in the Red River basin, either for forecasting or for studies. Hydrologic models use the moisture input to a basin, apply basin storage components, and calculate the streamflow at a given location by applying channel routing relationships.

Some models use statistical precipitation-runoff relations with routing equations, while others models are much more complex. Models could be classified as lumped or distributed, single event or continuous. Probabilistic models that take data uncertainties into account are also available. Model selection will depend on available data, basin or sub-basin characteristics, and the needs of the user.

A lumped model treats the watershed as a single unit for acquiring data and calculating runoff. The calculations are statistically based and relate to the underlying hydrologic processes as a spatially averaged process.

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* *Recommendation 8: Simplify and clarify communication between flood forecasters and those with local flood emergency responsibility, throughout the basin. The dissemination of forecast information to the public through the media should be simple and the variables inherent in those forecasts easily understood.* Interim Report of the International Red River Basin Task Force, Red River Flooding: Short-Term Measures, *December 1997.*

Some lumped models allow the watershed to be subdivided or allow some parameters to be physically estimated and modeled. When subdivisions of a basin are combined to produce an output, this modeling approach is termed semi-distributed. The present flood forecast models and the HEC-1 models used in the wetlands analysis are semi-distributed.

A distributed model simulates the key hydrologic processes that occur in a watershed using distributed data inputs and processes. These commonly include precipitation, interception, infiltration, interflow, and baseflow. Overland flow and channel routing may be incorporated into the model or calculated in a hydraulic model. Distributed models require much more data and knowledge of watershed processes than lumped, or semi-distributed, models. When the model is first established, gridded precipitation and land-cover characteristics may be the only distributed features.

Models used in channel routing calculate the travel time of the flood wave and its attenuation. Storage-flow relationships are often incorporated into hydrologic models. The one-dimensional unsteady flow hydraulic models described later in this chapter are used to route flows through multiple channels or where overland flow is a serious concern.

Red River Forecasting Liaison Committee - Proposed Terms of Reference

Review and implement procedures for the interchange of hydrometeorologic and related data among forecasting and operational agencies concerned with flow forecasting in the Red River basin in Canada and the United States.

Facilitate collaboration and information exchange on forecast methodology, data networks, data acquisition and communication systems, model development, and other related matters that would result in improved accuracy and timeliness of forecasts.

Consider how communication of forecasts to flood response agencies, other specialists, the media, and the general public could be improved.

Submit an annual report for each calendar year to member agencies and the IJC combined board by May 31of the following year. The report should identify progress during the year, specify data network changes, make recommendations as appropriate, and identify any changes to membership of the Committee.

Probabilistic models apply a mathematical distribution to input parameters such as precipitation forecasts, perhaps apply some random variables, and produce a large number of model runs that are statistically analyzed. The resulting forecast, rather than being a single outcome, provides an entire distribution of the future conditions. This approach is taken in the AHPS methodology used by NWS.

Simplified probabilistic methodologies that provide a range of possible forecasts have been used in the basin for some time. In them, the forecaster makes assumptions about future precipitation to determine runoff under normal and other conditions.

Issues concerning land use change, drainage, and runoff during summer floods and smaller spring floods can be approached through the application of distributed hydrologic models to one or more tributaries in the basin and eventually to the entire basin.

The issues raised in Chapter 3 concerning land use change, drainage, and runoff during summer floods and smaller spring floods can be approached through the application of distributed hydrologic models to one or more tributaries in the basin and eventually to the entire basin. This modeling would determine how sensitive the basin is to previous land use changes and would be able to examine the potential effects of permanent cover programs and changes to tillage practices on runoff. Coupling these models with medium-scale atmospheric models could lead to improvements in forecast models and some understanding of the effects of climate change on basin hydrology.

Recommendation 46: *Confirm the flood peak reduction findings of Chapter 3 for large floods and examine reductions for smaller floods by implementing distributed models on tributaries such as the Mistinka, Wild Rice and Maple Rivers.*

Recommendation 47: *As a long-term priority for government and academic research, implement a basin-wide coupled atmospheric-hydrologic model in the Red River basin.*

Hydraulics

In general, the channel of the Red River is capable of handling the runoff from a relatively modest flood, of a size that might occur one year in two. When the capacity of the channel is exceeded, the river overtops its banks and flows over the land. The extent of flooding depends on available water and the topography.

In larger floods, the river can overtop adjacent roads and railway embankments. The flow then moves north controlled not only by floodplain topography but also by roads and railways. These features confine the flow and sometimes act as obstructions to the flow. Consequently, water elevations in overland flow areas can be higher than those in the adjacent main channel. The overland flow may then return to the main channel with destructive force by breaching embankments. The 1997 flood resulted in a flooded area up to 25 miles (40 km) in width; many residents were flooded by overland flows.

The nature of the overland flow is highly variable in both space and time; some tributary streams may flow in reverse as the flood wave moves down the Red.

The nature of the overland flow is highly variable in both space and time; some tributary streams may flow in reverse as the flood wave moves down the Red. Sudden washouts of road and rail embankments and road cuts made by government personnel to reduce local water levels further complicate the picture.

The Red River basin models that existed at the time of the 1997 flood were not capable of dealing with complex overland flows. The Task Force sought computer models able to forecast overland flows during a flood and determine the effects of new dikes or reservoirs. Such models would be able to simulate:

- passage of a flood wave through complex topography and structures;
- flow over road and railway embankments;
- flow and storage changes related to new structural measures or modifications to existing structures;
- dividing flow among overland flow corridors; and
- changes in water levels caused by sustained wind.

Based on some preliminary work by Environment Canada's 1-D model, one-dimensional unsteady flow models met these needs for the most part. There are several of these models, all of which solve the same mathematical equations. They can simulate two-dimensional flows resembling those in the Red River basin.

The Task Force commissioned the development of two models aimed at simulating water levels to an accuracy of ±0.15 m, or 0.5 feet. In addition to developing models for real-time flood forecasting and planning purposes, the Task Force wished to examine the downstream effects of flood peak reduction scenarios, evaluate the spatial extent of floods larger than 1997, and define data and monitoring requirements associated with the models. With the exception of the lower Pembina River, discussed in Chapter 7, and the Sheyenne River, the models were applied only to the Red River itself, not the tributaries. Tributary inputs were based on streamflow data.

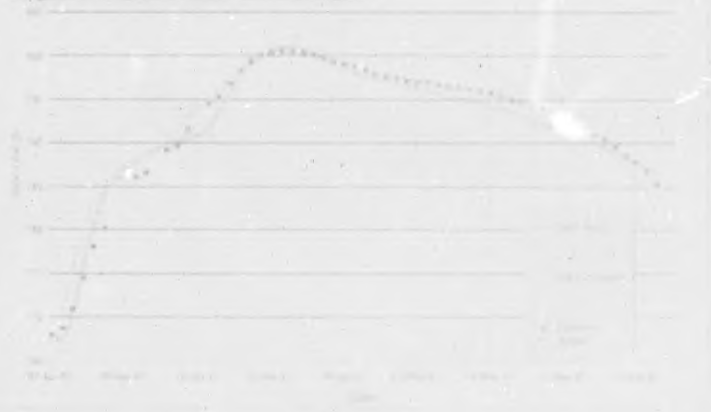
The Task Force commissioned the development of two models aimed at simulating water levels to an accuracy of ±0.15 m, or 0.5 feet.

To identify communities and roads on a map, and even individual homes and buildings at risk of flooding, the model output had to have a Geographic Information System format. The visual element greatly aids decision making.

The U.S. Army Corps of Engineers developed the one dimensional Unsteady NETwork (UNET) model of the basin for the IJC. It runs from the headwaters at Lake Traverse to Letellier, Manitoba. Under contract to the IJC, Klohn-Crippen Consultants Ltd. developed the MIKE 11 model, another one dimensional unsteady-state model with two dimensional capabilities, to run from Grand Forks to Selkirk. The overlapping sections of the models use the same input data. Both models were calibrated using the 1997 flood data and verified using 1996 and 1979 data. Calibration concentrated on meeting target accuracy near the peak water levels. Figure 12 shows an example of the performance of each model compared to recorded water levels.

Figure 12

Comparison of Hydraulic Model Results at Drayton



The UNET model was constructed to assess large-scale impacts of storage on hydrographs and to study timing and travel time of flood waves.

UNET Model

The UNET model was constructed to assess large-scale impacts of storage on hydrographs and to study timing and travel time of flood waves. Discharge hydrographs were routed down the rivers utilizing storage derived from cross-sectional geometry.

The model was constructed using river cross sections and other data previously developed for available HEC-2 one-dimensional steady state hydraulic models. These HEC-2 model inputs were converted to the UNET model by various methods using small computer programs and manual editing.

The UNET model covers 441 miles (710 km) of the Red River and Bois De Sioux River from the White Rock Dam near Lake Traverse to the town of Letellier in Manitoba. The Sheyenne River is also modeled from Kindred to its mouth on the Red River, some 87 river miles (140 km). There are 954 cross sections in the model and 11,000 lines of input.

Calibration of the UNET model involved a series of steps. First, inflow hydrographs from 27 gages were input along the main stem river at appropriate river mileage. Drainage area ratios of these gage records were used to produce initial inflow hydrographs for the ungaged areas as tributary gages record only a portion of the flows entering the Red River.

The model was initially run and discharges were computed at the USGS Red River gages. Based on a number of interactions, discharge is calibrated and water levels produced. Conveyance factors are used to adjust stage hydrographs to match recorded hydrographs and high water marks.

MIKE 11 simulates flooding in nine major Red River overland flow corridors and provides output to a geographic information system.

MIKE 11 Model

The MIKE 11 model, which extends 174 miles (280 km) from Grand Forks to Selkirk, becomes much more detailed from the confluence of the Pembina River north to Selkirk. A detailed sub-component of the model treats the lower Pembina River from upstream of Neche, North Dakota, to the Red River. MIKE 11 simulates flooding in nine major Red River overland flow corridors and provides output to a geographic information system.[46]

Several hundred Red River basin cross-sections were incorporated into the model. Road and rail embankments form the main hydraulic controls in the valley. Accurate elevations of rail lines and principal roads obtained in 1997 and 1998 were used in the model. This information was incorporated into a 500 m (1,640 feet) grid Digital Elevation Model to portray flooded areas and depths of flooding in the Geographic Information System.

Streamflow and water level data from 25 gaging stations helped calibrate the model. Water elevations from the overland flow areas and miscellaneous flow measurements taken during the 1997 flood supplemented this information. A particular problem was the flooding of some tributary gaging stations during the flood peak, which made data unavailable at those points. Estimated flows for this period were based on comparisons with upstream and adjacent sites.

Special measures were taken to account for ungaged flow in the UNET model.

Modeled water levels for 1997 met the target accuracy along the river and in the floodplain. The effects of ice cover prior to break-up were successfully simulated. The model was verified using 1996 and 1979 data. There were significant differences between the modeled peak water levels and recorded levels from Morris north to the Floodway inlet for 1979. These differences are likely caused by infrastructure changes in the last 20 years, notably construction of the Turnbull Drive dike and the raising of provincial road 200.

The model simulated two floods of 1826-type magnitude, analyzed the effects of upstream storage, determined the impact of the Seine River on Grande Pointe flooding, and reviewed the impact of a proposed drain from the Morris River to the Red River. The model demonstrated the sensitivity of water levels in the area upstream of the Floodway inlet to the quantity of water in the system. In effect, a river 25 miles (40 km) in width is suddenly confined to a very narrow cross-section at the Floodway. Accurate determination of effects in the area upstream of the Floodway is dependent therefore on having the accurate digital elevation model that was produced for the IJC.

The model indicates that water levels in floods of the order of 1826 would rise by less than a foot (0.3 m) over those experience in 1997 from Grand Forks to Morris. However, the effect at the Floodway entrance would be dramatic.

The model indicates that water levels in floods of the order of 1826 would rise by less than a foot (0.3 m) over those experience in 1997 from Grand Forks to Morris. However, the effect at the Floodway entrance would be dramatic. Levels could be expected to increase by six to seven feet (1.8 to 2.1 m) from 1997. If structural measures held, a questionable assumption under current conditions, water levels at James Avenue in Winnipeg would rise to 32 feet (9.75 m) compared to the flood protection level of 25.8 feet. (7.86 m)

FLDWAV Model

Like the UNET and MIKE 11 models, the NWS's Flood Wave (FLDWAV) model is a one-dimensional unsteady flow model. It was originally developed by the NWS to determine the water surface profile of the dynamic wave downstream of a dam failure.

The NWS first applied the model to the reach extending some 30 miles (42 kilometres) upstream from Oslo, North Dakota, to examine the water level discharge relationships at Grand Forks during the 1997 flood.[47] It simulated this situation well and has now been extended to include the reach from Halstad, Minnesota to Emerson, Manitoba. It is used by NWS hydrologists for post-flood analysis and real-time forecasting of natural and dam-break floods.

The topographic data used to represent the Red River and its floodplain came from cross-sections provided by the U.S. Army Corps of Engineers that were augmented by USGS 30-meter digital elevation model (DEM) derived cross-sections. Cross-sections for modeled tributary rivers were solely derived from the DEM. Streamflow information is provided from gaging stations and National Weather Service simulation models.

Phase 1 model development extends from Halstad to Emerson on the main stem Red River with five modeled tributary rivers. Initial calibration and testing of a simple model was completed in 1999 and is represented in this report. Complexities such as bridges, road embankments, and levees will be added in 2000.

Phase 2 development will extend from the headwater reservoirs of Lake Traverse on the Bois de Sioux River and Orwell Lake on the Ottertail River to Halstad. There are four modeled tributary rivers to the Red River in this phase. This work began in 1999 and will conclude in 2000.

The boundary conditions for the Phase 1 model comprise:

- discharge hydrographs from NWS hydrologic models for Halstad and the five gaged tributary rivers;
- five discharge hydrographs for the ungaged tributary areas from NWS hydrologic models; and
- water levels at Emerson.

The downstream boundary water levels are recorded values for calibration purposes and forecast values provided by Manitoba Water Resources for real-time forecast purposes.

The model was calibrated with data from two flood seasons: the extreme flood of March–May 1997 and the minor flood of 1999. Peak stages were simulated to within 0.5 feet (0.15 m) of the observed peak, with flow at the time of peak stage simulated to within 5 percent. The timing of the simulated-to-observed peak is within 12 hours. The calibration was validated with data from a moderate to major flood occurring from March to May 1996. The accuracy at the peaks is within that attained during calibration.

Future enhancements of this work will add complexities to the model to aid in the forecasting of extreme events as well as in the development of additional value-added products derived from the model, such as flood inundation maps for communities along the Red River.

Future Needs: Basin-wide

The accuracy of hydraulic models can be improved with more detail about the topography of the basin, enhancement of real-time data networks, and strengthened hydrologic understanding. The current models are for spring runoff. A separate calibration would be needed to make them useful during summer floods.

The goal remains to achieve a seamless, high-accuracy DEM for the basin.

During the course of the Task Force study, the topographic data were improved as described in Chapter 10. The Task Force conducted highly accurate Lidar surveys for the lower Pembina basin and south of Winnipeg. Other agencies collected Lidar data at Breckenridge and Fargo. The Task Force augmented this data with experimental IFSAR data in the lower Pembina and by GPS surveys of roads and rail lines in many parts of the basin. The goal remains to achieve a seamless, high-accuracy DEM for the basin. As surveys already exist for major roads and railways, the most significant topography-related improvement to benefit hydraulic modeling would come from GPS surveys of secondary roads.

Recommendation 48: *Conduct surveys of secondary roads, particularly in the central portion of the basin, with differential global positioning systems, and incorporate the results into the hydraulic models.*

Another asset for modeling floods in real time would be an ultrasonic flow meter at the narrows upstream of the Floodway. These devices measure stream discharge on a continuous basis. They would be invaluable for floodway operations and model calibration. This installation should be held in abeyance until decisions are made on Winnipeg flood protection. A similar flow meter at Grand Forks would also aid flood forecasts.

In addition, water level recorders at Breezy Point, Manitoba on the Red River and other floodplain locations would provide valuable data for the model. Streamflow data at key overland flow points such as Emerson and Morris would also improve model accuracy. Model calibration would be further enhanced through improved estimates of ungaged inflow using hydrologic models.

> **Recommendation 49:** ***The U.S. Army Corps of Engineers and Manitoba Conservation, operators of the UNET and MIKE 11 models respectively, should maintain the existing models and continue to seek improvements through collaboration with other agencies.***

> **Recommendation 50:** ***Measures should be taken to ensure that data supporting the operation of the hydraulic models and model outputs can be made widely available.***

Site Specific Future Needs

Floodway Entrance. Flood flows at the entrance to the Red River Floodway are made complex by the narrowing of the Red from a broad floodplain as it approaches the Floodway inlet structure. Existing and proposed community ring dikes have the potential to affect water levels in this area. Furthermore, wind and wave action make the West Dike vulnerable. The Floodway entrance is part of the existing MIKE 11 model, which can be used to simulate water levels for forecast operations and overcome some of the issues at the Floodway entrance. Despite that, a need has been identified for a more complex model to be used in a planning mode.[48] This portion of the basin is now being modeled using a two-dimensional finite element model known as TELEMAC.

Flood flows at the entrance to the Red River Floodway are complex.

The TELMAC model will simulate wind set-up on the West Dike, effects of dikes on water levels, and effects of modifications to the Floodway embankment on upstream water levels. The National Research Council of Canada is conducting this work under a Canada–Manitoba agreement.

12

Flood-Related Institutional Arrangements

Major floods capture attention and stimulate remedial action. But in a quiet period, between floods, the commitment to action declines as the immediacy and the apparent threat from flooding recedes. Flooding is a long-term problem, longer than most people's memories. The memory of 1997 needs to be kept alive.

Flooding is a long-term problem, longer than most people's memories. The memory of 1997 needs to be kept alive.

The actions recommended by the Task Force are not a one-time fix. They need to be implemented over time and adapted as circumstances change. The modeling and database work funded by the Task Force is leading-edge flood-management technology. Funding cutbacks, however, have limited what the Task Force hoped to accomplish. The virtual database and decision-support system work remains incomplete. The framework is in place, but government organizations will have to take responsibility for seeing the original conception through to completion, operation, expansion, and maintenance. The overlapping, compatible American and Canadian hydraulic models for the river developed by the Task force have proved useful. Because of funding limitations, however, much of the basin, particularly in the United States, has not been modeled. The tools that now exist will need to be maintained and improved as new information and new technologies emerge. And, as always, because the responsibility centers are in two countries, compatibility and integration of the systems being developed will remain an essential objective.

The Task Force sees the need for an institution with a basin-wide binational perspective to help keep flood management issues alive and to make progress toward resolving them for the people and governments of the basin. Management issues must, of course, remain the responsibility of the various governments. The governments themselves, however, have only a partial and occasionally a parochial perspective of flood- and water-related issues. They have at times worked effectively together, but it will always be difficult to bring a long-term cohesiveness of purpose and effective mutual support to a variety of agencies and governments, including federal governments, within and between jurisdictions.

Need for an institution with a basin-wide binational perspective to help keep flood management issues alive and to make progress toward resolving them.

The recommendations in the Task Force report, if accepted by the governments, will require ongoing monitoring, maintenance, development, and adjustment through existing or new institutions. Flood-related institutional arrangements are needed to:

1. ensure ongoing institutional support and full multi-jurisdictional participation for legacy projects, the distributed data base and computer models;
2. monitor implementation of recommendations designed to ensure basin-wide flood preparedness and community resiliency;
3. monitor and report on the implications of specific flood-related recommendations;
4. promote a culture of flood preparedness and flood resiliency in the basin;
5. support early warnings and early action in the face of impending major floods;
6. ensure binational coordination of flood forecasting and communications of forecasts to the public;
7. provide a forum for multi-jurisdictional problem solving;
8. provide a forum for the exchange of best practices information; and
9. provide knowledgeable and credible advocates to interact with the highest levels of government in order to help decision makers become aware of the requirements of the people of the basin on flood-related issues and associated issues of water management.

Flood management is part of the broader field of water management, and flood-related issues must often be part of broader water management strategies. For that reason, flood functions may need to be included in institutions with broad water-related responsibilities.

Current Institutional Setting

Any discussion of institutional arrangements must examine existing organizations.

Multiple interests coexist in the basin, and a number of organizations with flood-related functions support those interests. Any discussion of institutional arrangements must examine existing organizations with flood-related responsibilities, as well as proposals for new institutions that may be able to take on flood-related functions.

The Red River Basin Board, a major organization with water-related functions, represents a grass-roots effort to address issues in a basin-wide context. The Board is a not-for-profit corporation chartered under the laws of Manitoba, North Dakota, Minnesota, and South Dakota.

The board of directors has 21 members representing local government (cities, counties, and rural municipalities), watershed boards, water-resource districts, First Nations and Native Americans, a water supply cooperative, and a lake improvement association. There are also three at-large members, and some members have been appointed by the governors of North Dakota, Minnesota, and South Dakota and the premier of the Province of Manitoba.

The Board's mission is to develop a comprehensive water management plan, that would then be implemented by other agencies within the basin. It also seeks to serve as an information clearing house; to provide public information on basin issues; to serve as a forum for discussion, consensus building and dispute resolution, including inter-jurisdictional differences, in the management of surface and groundwater supplies in the Red River basin; and to provide advice to governments.

Red River Basin Board

Vision – The Red River Basin Board safeguards the region's lifeblood, its water, and the well-being of its residents. By 2010, residents of the region will be able to count on an ample year-round supply of good quality water. The Board will continue to work to ensure that lives and property will be safe from serious flooding.

Mission – The Red River Basin Board's mission is to create and implement a comprehensive water management plan for the Red River Basin. The Board also provides a forum for resolving interjurisdictional issues

The International Joint Commission itself has two boards with transboundary responsibilities in the basin, the International Red River Pollution Board and the International Souris–Red Rivers Engineering Board. The International Red River Pollution Board, established in 1969, maintains continuous surveillance over the quality of water and health of the transboundary aquatic ecosystem, and keeps the Commission informed of conditions and plans, policies, and developments which may adversely affect the quality of the water and the health of the ecosystem.

The International Souris–Red Rivers Engineering Board was established by the Commission in 1948 in response to a government request that it report on the use and apportionment of the waters within the Souris–Red River basin and that it develop plans of mutual advantage for these waters. The Board has been involved in numerous issues, including Red River flooding and diking problems, water supplies, and storage possibilities on the Pembina River.

The IJC, in cooperation with its two boards, is in the process of combining the boards and their responsibilities into one advisory board. This approach is intended to result in a more efficient and effective means for the IJC to fulfil its mandate in the basin.

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There are other basin-wide organizations. The Red River Water Resources Council works to enhance communication and cooperation between the governments and citizens of Minnesota, North Dakota, and Manitoba in managing water and related land resources for the benefit of the citizens of the Red River basin. Its predecessor, the Souris–Red–Rainy Basin Commission, was terminated by federal budgetary action in 1981. The seven-member board is made up of government-appointed representatives.

The International Coalition (TIC), a non-profit organization organized in 1979, was formed to see whether the Red River watershed could be managed on a regional basis. Its primary areas of involvement include building partnerships and establishing communication and cooperation among the people of Manitoba, Minnesota, North Dakota, and South Dakota in the Red River Basin. TIC's purpose is to educate and build consensus on basin-wide land and water issues.

International Flood Mitigation Initiative (IFMI)

Vision: By the year 2010, the community of the Red River Basin will address flooding through mitigation that achieves strong flood damage reduction goals and enhances economic, social, and ecological opportunities.

Strategies:

1. Comprehensive watershed storage and retention
2. Safe and sensible floodplain management
3. Landscape management for flood mitigation and other benefits

The International Flood Mitigation Initiative (IFMI) is a non-permanent organization formed following the 1997 flood by the North Dakota Consensus Council with funding from FEMA and the Province of Manitoba. The Initiative brings together representatives with a wide range of interests and expertise to focus on flood-related issues. IFMI seeks consensus among its members on recommendations for action and new institutional arrangements to prompt united action among basin residents to reduce the risk and consequences of Red River flooding. The Initiative terminates in 2000.

Within Minnesota and North Dakota there are a number of Red River basin institutions. In Minnesota, the Red River Watershed Management Board was created to institute, coordinate, and finance projects to alleviate flooding and to assure beneficial use of water in the watershed of the Red River and its tributaries. The scope of this board's jurisdiction and authority encompasses the area managed by the individual watershed districts represented on the board. The member districts include the Bois De Sioux, Buffalo–Red River, Joe River, Middle River–Snake River, Red Lake, Roseau River, Sand Hill River, The Two Rivers, and Wild Rice River.

The Minnesota Red River Basin Joint Powers Board was formed to enable participating counties to work together to develop comprehensive local water plans. Since completing the initial plans, the board has continued to meet on a regular basis to share information, discuss projects, and address land and water issues.

The North Dakota Red River Joint Water Resources Board is made up of 12 water-resource districts in the Red River Basin of North Dakota. It was formed to allow a coordinated and cooperative approach to planning and implementing a comprehensive water management program in the Red River Basin. Member districts include Ransom, Richland, Sargent, Walsh, Grand Forks, Traill, Maple, North Cass, Southeast Cass, Pembina, Nelson, and Steele.

The North Dakota/Minnesota Watershed Cooperation Board is formed from the Red River Joint Water Resources Board in North Dakota and the Red River Watershed Management Board in Minnesota. These two boards meet twice a year, once to exchange information and once to tour projects in either North Dakota or Minnesota.

In addition to these basin boards, there are tribal councils, conservation districts in Manitoba, water-resource districts and soil conservation districts in North Dakota, watershed districts and soil and water conservation districts in Minnesota, and special purpose water boards, as well as counties, municipalities, and cities within the basin that have a direct interest in water and flood management issues. The provinces, states and federal governments all have direct interests.

In 1998, the Commission recommended the creation of international watershed boards, including one for the Red River.

IJC Watershed Board Concept

In 1998, the IJC reflected on the issues facing Canada–United States transboundary environmental relations in the twenty-first century. In its report ***The IJC and the 21st Century***, the Commission recommended the creation of international watershed boards, including one for the Red River. The proposal builds on cooperative efforts and successes achieved by the Commission in past binational initiatives. The boards would apply an ecosystem approach to transboundary watershed issues. They would seek to prevent and resolve transboundary disputes and promote transboundary cooperation on matters of mutual interest by building a capacity at the watershed level to anticipate and respond to water-related and other environmental challenges. The boards would be independent, objective bodies that could link local residents and organizations to the national decision-making structures, and ensure a binational watershed focus.

Watershed Board Reference

After publication of the IJC report *The IJC and the 21st Century*, the governments of Canada and the United States approved the watershed board concept in principle and asked the IJC to:

1. define the general framework under which watershed boards would operate, including the scope of activities of the watershed boards and the operating principles of such boards;
2. recommend the location of the first watershed board;
3. recommend the structure, composition and terms of reference of the first international watershed board, including the priority issues it would address;
4. develop cost projections and possible sources of funding, including innovative funding mechanisms, for the formation and operation of the first international watershed board and for financing special studies that would be projected for its first few years of operation; and
5. consult provinces, states, and both federal governments to identify locations and to develop, plan and establish additional international watershed boards at appropriate times.

The governments of Canada and the United States have accepted the watershed board concept in principle and asked the Commission to develop the concept further (see box). If the governments and the Commission decide to implement the watershed board concept, they may consider establishing one of the boards in the Red River basin.

New Basin-wide Approaches

There are a number of considerations and criteria in proposing institutional arrangements for transboundary river basins. For one, they need to able to deal with issues in a timely and efficient manner. Ideally, the line dividing the countries should not hinder the achievement of outcomes that could be attained within a single jurisdiction. Realistically, ideal technical solutions must be modified by political considerations. International and domestic equity issues are part of these considerations.

For Canada and the United States, domestic equity requires an accommodation of contending political, economic, and other interests. Institutional arrangements must therefore be responsive to public concerns and interests. They must also be accountable to the public that will be affected by actions taken. An underlying consideration for both efficiency and equity concerns is the need for good information. Information is needed to keep governments and the public abreast of emerging problems and opportunities, their nature, the options for dealing with them, their costs and benefits, and how they will be distributed between and within the countries. Where there is agreement on international action, it is also essential to evaluate the problems encountered and the progress being made.

International institutional arrangements must be situated within a context that reflects the legitimate concerns of national governments and the interests they represent. To be relevant, they must be able to reconcile technical possibilities with the political realities of how governments work with their citizens and their neighbors.

A basin-wide approach to water management is generally accepted within the Red River basin.

The concept of a basin-wide approach to water management is generally accepted within the Red River basin. Opinions differ as to the most suitable types of institutions and their mandates. The Red River Basin Board embodies the view that a basin-wide institution should emerge from local authorities. Other views favor an even broader representative approach. Some people look to other river basin institutions, such as the Tennessee Valley Authority, for an institutional model. However, there is recognition that there may be insuperable problems in removing institutional authority from sovereign state, provincial, and federal governments through legislation and international agreements.

In contrast, IJC boards are established by the IJC under authority derived from the Boundary Waters Treaty and the references given to the Commission by the two national governments. The Commission in its work seeks to engage the public and local interests. While the legitimacy of groups like the Red River Basin Board comes from its support at the local level, the legitimacy of IJC boards stems from the authority granted by senior levels of government. Members of IJC boards are generally federal, state, and provincial officials acting in a personal or professional capacity.

A two-tier approach, in which basin institutions work cooperatively, could meet the institutional need for flood-related and associated issues.

There is debate about which approach is the most appropriate to prepare the basin for flooding problems. The Task Force believes that to accommodate the considerations raised above, a two-tier approach, in which basin institutions work cooperatively, could meet the institutional need for flood-related and associated issues. A first-tier organization is one established by the authority of state, provincial, and federal governments, although, like IJC boards, they may operate independently of governments. Second-tier organizations emerge from initiatives at the local, regional, or basin level. The interests of the two types of organizations may overlap, but their membership, accountability structures, and the way they operate will differ.

There is no doubt about the need for regional and basin-wide organizations that are accountable to basin communities and groups, that can reflect and advocate local and regional interests and present consensus among them. The Red River Basin Board, one organization that currently has this function, would be characteristic of a second-tier organization.

There is also a case for a first-tier organization attuned to the complexities of dealing with international issues while interacting with governments and basin interests. Such an organization would need to develop the confidence of federal, state, and provincial governments, and be accepted by local governments, non-governmental organizations, and the public as the appropriate body for dealing with basin issues having transboundary implications.

...first-tier organization attuned to the complexities of dealing with international issues while interacting with governments and basin interests.

The strength of such an organization would be in its advisory role in relation to national, state, and provincial governments. It would have no water management responsibilities. It would not alter current federal, provincial, and state responsibilities. It would build on existing IJC institutions and be designed to help ensure that each jurisdiction fulfills its water-related responsibilities to the public and to each other.

No first-tier transboundary flood-related organization or board now exists, and a number of issues need to be fully considered before one can be created. The Task Force has heard concerns about the duplication of existing institutions and possible over-representation of federal perspectives and under-representation of state, provincial, and local perspectives. These concerns are addressed in the discussion that follows.

Principles

The following principles would be crucial to ensuring the acceptability, credibility, and effectiveness of a first-tier international transboundary body for flood-related purposes:

1. Equality of representation between the two countries
2. Appropriate expertise of members serving in their personal and professional capacity
3. Decision-making by consensus
4. Public consultation with second-tier organizations and the public
5. Consultation with the public and the media on public policy issues
6. Direct access to governments
7. Access to sufficient funds to undertake essential research and analysis in support of assigned functions

No single organization could effectively encompass the total array of interests and views within a basin.

A first-tier transboundary flood-related body of the kind contemplated by the Task Force would need to be able to respond to emerging local issues and, where appropriate, to help resolve the issues at the local level. It would have enough flexibility to be able to act to prevent local issues from becoming issues of wider or binational concern. It would work with local interests and, where appropriate, with other basin institutions in the kind of two-tier approach suggested above.

Principles considered critical for the operation of second-tier organizations include:

1. Involvement to the highest degree possible with people of the basin
2. Adequate representation of stakeholders
3. A wide range of representative views in the basin in organization discussions
4. Consensus in views brought forward to governments and first-tier organizations
5. Access to sufficient funds to support assigned functions

It should be recognized that no single organization could effectively encompass the total array of interests and views within a basin. Single-issue interests and broad-based interests may not be able to work together. What is important is that the range of organizations should reflect the issues and interests of concern to people in the basin, and that these views should be fully considered by governments and first-tier institutions.

An important principle that distinguishes the IJC from other international river institutions is that its board members are asked to serve in their personal and professional capacities.

Representation

A first-tier transboundary flood-related institution would require state and provincial membership. An important principle that distinguishes the IJC from other international river institutions, such as the International Commission for the Protection of the Rhine, is that its board members are asked to serve in their personal and professional capacities. The members of most other international commissions are appointed by and represent their governments. The IJC approach promotes a problem-solving, rather than negotiating approach to transboundary issues. This representation principle encourages a basin-wide public interest perspective.

While serving in their professional capacity, government members would have a special role in coordination, facilitation, and consensus building. Their knowledge and direct contact and consultation with their agencies would facilitate appropriate action on emerging and current issues.

With only state, provincial, and federal members, a transboundary flood-related body might not sufficiently reflect local concerns and interests. On the other hand, if it tried to include a representative range of basin interests, the problem would arise as to who should be included and excluded, and how large the board could be and still function effectively.

Canadian and American members might be included from the Red River Basin Board or non-governmental organizations. The Red River Basin Board includes representatives from many local government organizations, as well as the states and provinces, but it does not encompass the full range of basin interests, for example those of environmental and other non-governmental organizations.

The choice is between institutional effectiveness and representation.

Ultimately, the choice is between institutional effectiveness and representation. In the view of the Task Force, large numbers limit effectiveness. An optimal number may be roughly from 10 to 12 members, an equal number from each country in keeping with the equality principle. Such a body could include state and provincial members with water-related and environmental responsibilities, as well as federal officials and others with similar interests, including emergency management. The body could include some members from outside of government who can bring special expertise to bear.

Whichever approach is adopted, a transboundary flood-related body could function effectively only if it enthusiastically sought consultation and public discussion. Clearly not everyone can be represented, but the vast majority can be heard and their views respectfully considered. Major institutions, such as the Red River Basin Board and other second-tier non-governmental organizations, should be an essential part of consultations. Formal arrangements could be established to ensure the participation of the Red River Basin Board and other organizations in deliberations of the transboundary flood-related institution.

Reporting Relations

A transboundary flood-related institution would be expected to work closely with federal, state, and provincial governments. If part of the IJC structure, it would report regularly to the Commission and through it to the federal governments. It should also formally and regularly present its proposals and recommendations directly to state and provincial governments. Moreover, state and provincial governments should be able to raise questions and make proposals to the body on issues of concern and request it to take action.

State and provincial governments should be able to raise questions and make proposals to the body on issues of concern and request it to take action.

Resources

Much of the normal work of a transboundary flood-related institution could be carried out with relatively modest financial resources. As with IJC boards, home agencies of board members should be able to absorb much of the membership costs. But agency volunteerism has its limits. Government departments are increasingly unwilling to divert scarce agency resources to outside initiatives. For a transboundary institution to be fully effective, it would need to be able to obtain funds from the federal governments to address issues of particular importance requiring the work of specialists and consultants.

In addition, a transboundary institution would need resources for a small secretariat to ensure continuity and ongoing support for its regular work. The secretariat would include co-secretaries whose duties in their home organization would include work with the institution.

Conclusion 9: ***It is for the Commission and the governments to ratify an international watershed board for the Red River basin. The Task Force, however, considers that such a board, if established, might appropriately be assigned a mandate to advocate and report on flood-related issues, including the progress of governments in implementing the recommendations in this report and in maintaining and advancing the work of the Task Force's legacy projects. More particularly, this mandate could include the flood-related functions identified earlier in this section, namely, to:***

1. ***Ensure ongoing institutional support and full multi-jurisdictional participation for legacy projects, the distributed data base, and computer models;***
2. ***Monitor implementation of recommendations designed to ensure basin-wide flood preparedness and community resiliency;***
3. ***Monitor and report on the implications of specific flood-related recommendations;***
4. ***Promote a culture of flood preparedness and flood resiliency in the basin;***
5. ***Support early warnings and early action in the face of impending major floods;***
6. ***Ensure coordination of flood forecasting information;***
7. ***Provide a forum for multi-jurisdictional problem solving;***
8. ***Provide a forum for the exchange of best-practices information; and***
9. ***Provide knowledgeable and credible advocates to interact with the highest levels of government in order to make decision makers aware of the requirements of the people of the basin on flood-related issues and associated issues of water management.***

Given these functions, the Task Force advocates including the following in the Board's structure and reporting responsibilities:

- ***A membership of 10 to 12 members, with representatives from the states of North Dakota and Minnesota, the province of Manitoba, and the two federal governments, plus outside experts as appropriate***
- ***Regular formal and informal consultation with other basin organizations and local governments***
- ***Reporting to the two federal governments and, as appropriate, the state and provincial governments***
- ***Direct communication with the public and media***

Flood-related institutional arrangements of this nature would have the great advantage of being founded on the IJC's time-proven principles of equality of representation, independence, and objectivity.

Recommendation 51: ***If the International Joint Commission pursues the watershed board concept, the Commission should consider establishing its initial board in the Red River basin and assigning to this board the flood-related responsibilities outlined above.***

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Conclusions and Recommendations

Conclusions

Red River in History

Conclusion 1: Analysis of the geological record, historic floods of the nineteenth century, statistics, and the hydrometeorological factors that cause floods in the Red River basin indicate that floods of the same size as in 1997, or even greater, can be expected in the future.

Flow Management

Conclusion 2: It would be difficult if not impossible to develop enough economically and environmentally acceptable large reservoir storage to reduce substantially the flood peaks for major floods.

Conclusion 3: Large-scale micro-storage has some potential to reduce flood peaks on the Red River but is likely to be impracticable and costly. There are many obstacles to its effective and efficient implementation.

Conclusion 4: Wetland storage may be a valued component of the prairie ecosystem but it plays an insignificant hydrologic role in reducing peaks of large floods on the main stem of the Red River.

Conclusion 5: There may be many good environmental and other reasons to restore wetlands, but wetland restoration is an economically inefficient method of reducing flood damages for infrequent large floods, like the Red River flood of 1997.

Winnipeg at Risk

Conclusion 6: Under flow conditions similar to those experienced in 1997, the risk of a failure of Winnipeg's flood protection infrastructure is high.

Lower Pembina River Flooding

Conclusion 7: There is general recognition in the region that flooding in the lower Pembina River basin has been profoundly affected by the construction of dikes and of roads that act as dikes on both sides of the boundary. Rectifying the transboundary flooding consequences of these structures will require action in both countries and there appears to be a general readiness to take such action.

Data and Decision Support for Flood Management

Conclusion 8: Further improvement and maintenance of the Red River floodplain management database is required. Federal, state and provincial governments and local authorities must maintain a high level of involvement in further database development and in improving data accessibility.

Flood Related Institutional Arrangements

Conclusion 9: It is, of course, for the Commission and the governments to ratify an international watershed board for the Red River basin. The Task Force, however, considers that such a board, if established, might appropriately be assigned a mandate to advocate and report on flood-related issues, including the progress of governments in implementing the recommendations in this report and in maintaining and advancing the work of the Task Force's legacy projects. More particularly, this mandate could include these flood-related functions:

1. Ensure ongoing institutional support and full multi-jurisdictional participation for legacy projects, the distributed data base, and computer models.
2. Monitor implementation of recommendations designed to ensure basin-wide flood preparedness and community resiliency.
3. Monitor and report on the implications of specific flood-related recommendations.
4. Promote a culture of flood preparedness and flood resiliency in the basin.
5. Support early warnings and early action in the face of impending major floods.
6. Ensure coordination of flood forecasting information.
7. Provide a forum for multi-jurisdictional problem solving.
8. Provide a forum for the exchange of best-practices information.
9. Provide knowledgeable and credible advocates to interact with the highest levels of government in order to make decision makers aware of the requirements of the people of the basin on flood-related issues and associated issues of water management.

Given these functions, the Task Force advocates including the following in the Board's structure and reporting responsibilities:

1. A membership of 10 to 12 members, with representatives from the states of North Dakota and Minnesota, the province of Manitoba, and the two federal governments, plus outside experts as appropriate
2. Regular formal and informal consultation with other basin organizations and local governments
3. Reporting to the two federal governments and, as appropriate, the state and provincial governments
4. Direct communication with the public and media

Recommendations

Flow Management

Recommendation 1: Wetland restoration projects for flood control should be evaluated on the basis of their local benefits and costs rather than imputing a basin-wide benefit.

Recommendation 2: Future ice jam information from the entire basin should be incorporated into the CRREL Ice Jam Database so that ice problems in the basin can be analyzed further. Where feasible, historic ice jams from the Canadian portion of the basin should be entered.

Communities at Risk

Recommendation 3: Communities in the United States portion of the Red River basin should ensure that community-built flood damage reduction projects are certified by FEMA for 100-year or greater protection, or should participate in the Non-Federal Flood Control Works Inspection Program.

Winnipeg at Risk

Recommendation 4: The design flood used as the standard for flood protection works for Winnipeg should be the highest that can be economically justified or, at a minimum, the flood of record, the 1826 flood.

Recommendation 5: Based on results from hydraulic model studies, modify the east embankment of the Floodway to improve the performance of the Floodway entrance to lower upstream water levels and increase capacity.

Recommendation 6: The west dike should be raised to allow a water level elevation of 778 feet (237 m) at the Floodway inlet structure with appropriate freeboard.

PFRA

West Dike, Winnipeg, Manitoba

Recommendation 7: The primary diking system should be raised where economically feasible to the elevation specified in existing legislation.

Recommendation 8: The City of Winnipeg, the province, and the federal government should cooperatively finance detailed feasibility studies of the two major projects that would protect Winnipeg against very large floods.

Recommendation 9: The three jurisdictions should work towards a Winnipeg Protection Agreement to finance the development of a long-term protection plan that would include construction of the Ste. Agathe Detention Structure or Floodway expansion.

Recommendation 10: Modifications to the sewer and land drainage systems should be optimized and undertaken once the overall plan for Winnipeg flood protection is determined.

Recommendation 11: The City of Winnipeg should give immediate high priority to the preparation of a detailed emergency preparedness and response manual.

Recommendation 12: Operating rules for new flood control measures should be designed to accommodate all flow regimes, even those beyond design capacity. The public should be consulted on any proposed new operating rules.

Flood Preparedness and Resiliency

Recommendation 13: In the U.S. portion of the Red River basin, the 100-year floodplain should continue to be defined in light of the best available information and the revised flood elevations should be used as the basis for floodplain regulations.

Recommendation 14: In Manitoba, either the flood of record or the one-percent flood should be used for Red River basin regulations.

Recommendation 15: The 500-year flood (0.2 percent flood) should be defined throughout the Red River basin and used to inform the public of the potential risks of flooding from rare events, including the need to buy flood insurance in the United States, and as the basis of regulations for siting and floodproofing critical facilities.

Recommendation 16: Both North Dakota and Minnesota should consider adopting the new International Building Code that includes requirements for design and construction in flood hazard areas.

Recommendation 17: The National Building Code of Canada should specify design and construction standards for buildings in flood hazard areas such as the Red River basin. Floodplain construction requirements should be incorporated into the Manitoba code when available.

Recommendation 18: Federal, state, provincial, and local governments in the Red River Basin, in conjunction with the private sector, should continue to develop, refine, and implement effective strategies to improve the disaster resiliency in basin communities. Efforts should be made to increase public awareness of flood risks throughout the basin.

Recommendation 19: State, provincial and other appropriate authorities should review the effectiveness of and compliance with the floodplain management regulations in the basin and take steps as needed to improve enforcement.

Recommendation 20: While the restriction of reuse of acquired properties is prudent as applied to residential, commercial or other non-flood damage mitigation purposes, FEMA should revise its interpretation of "structures" under the Hazard Mitigation Grant Program regulations to exempt water level control devices, dikes, levees, flood walls and any other feature that would mitigate future flood losses.

Recommendation 21: The Canadian federal government should include in the Disaster Financial Assistance Arrangements provisions to allow for the permanent removal of structures in areas subject to repeated flooding.

Recommendation 22: FEMA and Emergency Preparedness Canada should develop an integrated approach to mitigation initiatives at all political levels based on a comprehensive mitigation strategy for the entire basin. In the United States, the strategy should be integrated within the National Mitigation Strategy.

Recommendation 23: The Canadian federal government should establish a national flood mitigation strategy, or a broader disaster mitigation strategy, and support it with comprehensive mitigation programs.

Recommendation 24: In the U. S. portion of the Red River basin, FEMA should expand current efforts to market the sale and retention of flood insurance both within and outside the 100-year floodplain. Innovative marketing should be considered to attract and retain policy holders, including increasing the waiting period from 30 days to 60 days before flood insurance comes into effect.

Recommendation 25: Recovery, rebuilding, and mitigation expertise and information should be widely shared across the border in advance of flooding.

Recommendation 26: Measures of flood resilience should be developed, and a system should be established to monitor resilience in the Red River basin.

Flooding in the Lower Pembina River

Recommendation 27: The International Technical Working Group, formed in 1996 but currently inactive, should be re-activated to examine the findings of the hydrodynamic model. Working with local interests, such as the Pembina River Basin Advisory Board, it should develop, implement, and fund a solution that is sustainable in the long term.

Recommendation 28: Given the transboundary nature of the basin and the potential for federal involvement in funding and monitoring any agreement, federal agencies from both countries should be engaged in this process as well.

Recommendation 29: Changes in the road network and diking system in the lower Pembina basin should be modeled by the hydrodynamic model prior to implementation of any plan to ensure that there are no unintended consequences.

Recommendation 30: The virtual database and decision support system prototype that the Task Force has begun to develop for the Pembina basin should be continued by relevant agencies in Canada and the United States.

Hydraulic Connections at Lake Traverse

Recommendation 31: Engineering studies should be immediately undertaken to examine all means of eliminating the potential for the hydraulic inter-basin connection in the vicinity of Browns Valley. Governments should then implement the most feasible option. During the interim, the Little Minnesota River system should be closely monitored for undesirable species. If such species appear, immediate action should be taken to prevent their transfer to the Red River basin.

Since benefits accrue basin-wide from coordinated actions taken to prevent the movement of non-native species between adjacent basins, local governments should not be held responsible for costs associated with monitoring or implementing corrective measures. While the U.S. Army Corps of Engineers will need to take the lead role in implementing this recommendation, cost-sharing options should be negotiated with Canada because of the basin-wide benefits.

Recommendation 32: Any modification to existing operating plans or physical structures associated with Lake Traverse that could increase pool elevation must be accompanied by features that eliminate the southward movement of water into the Little Minnesota River.

Lake Winnipeg Water Quality

Recommendation 33: Governments should take immediate steps to ensure that all banned materials such as toxaphene are removed from storage areas in the Red River basin and that potentially hazardous materials are not stored in the 500-year floodplain. Reasonable quantities of such substances could be maintained in the floodplain for immediate use.

Recommendation 34: Governments should continue to monitor toxaphene in the Lake Winnipeg ecosystem until concentrations decline to pre-1997 levels.

Data and Decision Support for Flood Management

Recommendation 35: Hydrometric and meteorological data networks necessary for flood forecasting should be improved and maintained in a state of readiness to forecast future floods.

Recommendation 36: New geographically related data collection in the United States should be in accord with the North American Vertical Datum of 1988.

Recommendation 37: For consistency and accuracy data used in models should take into account the differences in data at the border. Because datum conversions can affect data accuracy, any conversions between standards should be noted and reported along with the data.

Recommendation 38: U.S. National Geodetic Survey and the Geodetic Survey of Canada should convene a forum of datum experts in the year 2000 to discuss Red River basin datum issues and develop a long-term transition plan.

Recommendation 39: All key data providers in Canada should make available at no cost and with no restriction the data sets necessary for the Red River floodplain management and emergency response, and regional or basin-wide modeling activities.

Recommendation 40: Data providers should remain responsible for maintaining and replicating the data sets.

Recommendation 41: Development of the digital elevation model for the Red River Basin should be completed by collaborative initiatives of the relevant agencies.

Recommendation 42: Relevant federal, provincial, state agencies and transboundary agencies should meet to determine the interest in continuing the work of RRBDIN and if there is agreement to continue it, draw up a funding and action plan to ensure its continuation.

Recommendation 43: A decision on whether to continue operation of the Virtual Forum should be included in the discussions on the continuation of the RRBDIN.

Hydrologic and Hydraulic Modeling

Recommendation 44: The U.S. National Weather Service should implement its Advanced Hydrologic Prediction System in the Red River basin as an early priority.

Recommendation 45: A binational Red River Flood Forecasting Liaison Committee should be established by government to improve communications among forecasters and with the public.

Recommendation 46: Confirm the flood peak reduction findings of Chapter 3 for large floods and examine reductions for smaller floods by implementing distributed models on tributaries such as the Mistinka, Wild Rice and Maple Rivers.

Recommendation 47: As a long-term priority for government and academic research, implement a basin-wide coupled atmospheric-hydrologic model in the Red River basin.

Recommendation 48: Conduct surveys of secondary roads, particularly in the central portion of the basin, with differential global positioning systems, and incorporate the results into the hydraulic models.

Recommendation 49: The U.S. Army Corps of Engineers and Manitoba Conservation, operators of the UNET and MIKE 11 models respectively, should maintain the existing models and continue to seek improvements through collaboration with other agencies.

Recommendation 50: Measures should be taken to ensure that data supporting the operation of the hydraulic models and model outputs can be made widely available.

Flood Related Institutional Arrangements

Recommendation 51: If the International Joint Commission pursues the watershed board concept, the Commission should consider establishing its initial board in the Red River Basin and assigning to this board flood-related responsibilities.

Appendix 5

Proposed Directive for International Red River Board

1. Pursuant to the Boundary Waters Treaty of 1909, responsibilities have been conferred on the Commission under a 1948 Reference from the governments of Canada and the United States with respect to the use and apportionment of the waters along, across, or in the vicinity of the international boundary from the eastern boundary of the Milk River drainage basin on the west up to and including the drainage basin of the Red River on the east, and under the May 1969 authorization from the governments to establish continuous supervision over the quality of the waters crossing the boundary in the Red River and to recommend amendments or additions to the objectives when considered warranted by the International Joint Commission.

2. This directive replaces previous directives and instructions provided by the International Joint Commission to the International Souris-Red Rivers Engineering Board, and in the February 8, 1995 Directive to the International Red River Pollution Board. This Directive consolidates the functions of those two former boards into one board, to be known as the International Red River Board (Board).

3. The Board's mandate is to assist the Commission in preventing and resolving transboundary disputes regarding the waters and aquatic ecosystem of the Red River and its tributaries and aquifers. This will be accomplished through the application of best available science and knowledge of the aquatic ecosystem of the basin and an awareness of the needs, expectations and capabilities of residents of the Red River basin.

4. The geographical scope of the Board's mandate shall be the Red River basin, excluding the Assiniboine and Souris Rivers. The Board's activities shall focus on those factors which affect the Red River's water quality, water quantity, levels and aquatic ecological integrity.

5. The Board's duties shall be to:

   A. Maintain an awareness of basin-wide development activities and conditions that may affect water levels and flows, water quality and the ecosystem health of the Red River and its transboundary tributaries and inform the Commission about transboundary issues.

B. Provide a continuing forum for the identification, discussion and resolution of existing and emerging water-related issues relevant to the Red River basin.

C. Recommend appropriate strategies to the Commission concerning water quality, quantity and aquatic ecosystem health objectives in the basin.

D. Maintain continuing surveillance and perform inspections, evaluations and assessments, as necessary, to determine compliance with objectives agreed to by governments for water quality, levels and quantity in the Red River basin.

E. Encourage the appropriate regulatory and enforcement agencies to take steps to ensure that agreed objectives are met.

F. Encourage the appropriate authorities, such as resource and emergency planning agencies, to establish and maintain contingency plans, including early warning procedures, for appropriate reporting and action on accidental discharges or spills, floods and droughts.

G. Monitor and report on flood preparedness and mitigation activities in the Red River basin and their potential effects on the transboundary aquatic ecosystem, and encourage and facilitate the development and maintenance of flood-related data and information systems and flood forecasting and hydrodynamic models. In carrying out this responsibility, the Board shall:

   i. Monitor progress by the governments (federal, state, provincial, municipal) in implementing the recommendations of the Commission's report on Red River basin flooding, and in maintaining and advancing the work of the Task Force's legacy projects.

   ii. Encourage governments to develop and promote a culture of flood preparedness in the Red River valley.

   iii. Encourage government efforts to develop and implement a long- term strategy for flood mitigation and emergency preparedness.

   iv. Encourage the sharing of accurate and timely transboundary information to support the development of improved flood forecasting techniques and procedures for early flood warnings and to improve communication of flood forecasts.

   v. Provide through the activities of the Board a forum for the exchange of best practices and for other flood-related information on preparedness, mitigation, response, and recovery, to assist in transboundary problem solving.

   vi. Promote the application of innovative technologies for supporting flood modeling and mapping.

   vii. Monitor the adequacy of data and information collection networks (meteorological, hydrometric, water quality) for flood preparedness, forecasting and mitigation, within the larger context of overall water management needs in the basin.

viii. Monitor potential transboundary effects of flood mitigation and other works in the basin, and encourage cooperative studies necessary to examine these effects.

ix. Encourage governments to integrate floodplain management activities in watershed and basin management.

x. Interact with all levels of government to help decision-makers become aware of transboundary flood-related and associated water management issues.

xi. Assist in facilitating a consultative process for resolution of the lower Pembina River flooding issue.

H. involve the public in the work of the Board, facilitate provision of timely and pertinent information within the basin in the most appropriate manner including electronic information networks, and conduct an annual public meeting in the Red River basin;

I. provide an annual report to the Commission, plus other reports as the Commission may request or the Board may feel appropriate in keeping with this Directive.

J. maintain an awareness of the activities of other agencies and institutions, in the Red River basin;

7. The Board shall continue to report on the non-Red River geographic areas under the responsibility of the former International Souris-Red Rivers Engineering Board, including the Poplar and Big Muddy basins, until the Commission determines otherwise.

8. The Board shall have an equal number of members from each country. The Commission shall normally appoint each member for a three-year term. Members may serve for more than one term. Members shall act in their personal and professional capacity, and not as representatives of their countries, agencies or institutions. The Commission shall appoint one member from each country to serve as co-chairs of the Board. An alternate member may not act as a co-chair.

9. At the request of any member, the Commission may appoint an alternate member to act in the place of such member whenever the said member, for any reason, is not available to perform such duties as are required of the member.

10. The co-chairs of the Board shall be responsible for maintaining proper liaison between the Board and the Commission, and among the Board members. Chairs shall ensure that all members of the Board are informed of all instructions, inquiries, and authorizations received from the Commission and also of activities undertaken by or on behalf of the Board, progress made, and any developments affecting such progress.

11. Each chair, after consulting the members of the Board, may appoint a secretary. Under the general supervision of the chair(s), the secretary(ies) shall carry out such duties as are assigned by the chairs or the Board as a whole.

12. The Board may establish such committees and working groups as may be required to discharge its responsibilities effectively. The Commission shall be kept informed of the duties and composition of any committee or working group. Unless other arrangements are made, members of the Board, committees, or working groups will make their own arrangements for reimbursement of necessary expenditures.

13. The Commission should also be informed of the Board's plans and progress and of any developments or cost impediments, actual or anticipated, which are likely to affect carrying out the Board's responsibilities.

14. The Commission shall be informed, in advance, of plans for any public meetings or public involvement in the Board deliberations. The Board shall report, in a timely manner, to the Commission on these meetings, including representations made to the board.

15. The Board shall provide the text of media releases and other public information materials to the Secretaries of the Commission for review by the Commission's Public Information Officers, prior to their release.

16. Reports, including annual reports, and correspondence of the Board shall, normally, remain privileged and be available only to the Commission and to members of the Board and its committees until their release has been authorized by the Commission.

17. If, in the opinion of the Board or of any member, any instruction, directive, or authorization received from the Commission lacks clarity or precision, the matter shall be referred promptly to the Commission for appropriate action.

18. In the event of any unresolved disagreement among the members of the Board, the Board shall refer the matter forthwith to the Commission for decision.

19. The Commission may amend existing instructions or issue new instructions to the Board at any time.

Signed this ___ day of _______________, 2001

Gerald E. Galloway Secretary United States Section	Murray Clamen Secretary Canadian Section